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A TWO-YEAR STUDY OF THE ROCKY MOUNTAIN GOAT IN THE CRAZY MOUNTAINS, MONTANA [1]

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The Montana Fish and Game Department has conducted a program of live-trapping and transplanting Rocky Mountain goats (*Oreamnos americanus missoulae*) into "new" areas. Twenty-one were transplanted into the Crazy Mountains, southwestern Montana, as follows: two mature females, one mature male, and one yearling male April 16, 1941; three females and two males two years old or older and one yearling female April 26, 1941; six females and four males two years old or older, and one yearling female April 17, 1943. All were released along Sweetgrass Creek a few miles above the Brannin Ranch (Fig. 1). Mr. Barney M. Brannin, a rancher in Sweetgrass Canyon, requested the stocking. He solicited half the necessary funds from residents of the Crazy Mountains area and helped Game Department personnel trap the original stock on Deep Creek west of Choteau in the northwestern part of the state.

Each year following the plants, Mr. Brannin placed block salt along the high, rough ridge on the north side of Sweetgrass Creek and in Milly Creek, a tributary. Each successive year the salt was placed at lower elevations and each year it was used by goats. Mr. Brannin recorded observations each year, mostly in May and June during the kidding season. New kids were observed each spring. His diary reveals a gradual increase in numbers.

This highly successful planting provided an opportunity to conduct an intensive investigation of an expanding herd in a new environment. Data were procured on populations, movements, reproduction, and other biological factors from March, 1952, to October, 1953. The findings provide a basis for comparison with older stabilized goat herds of the state, chiefly those of the Continental Unit studied by Casebeer, *et al.* (1950).

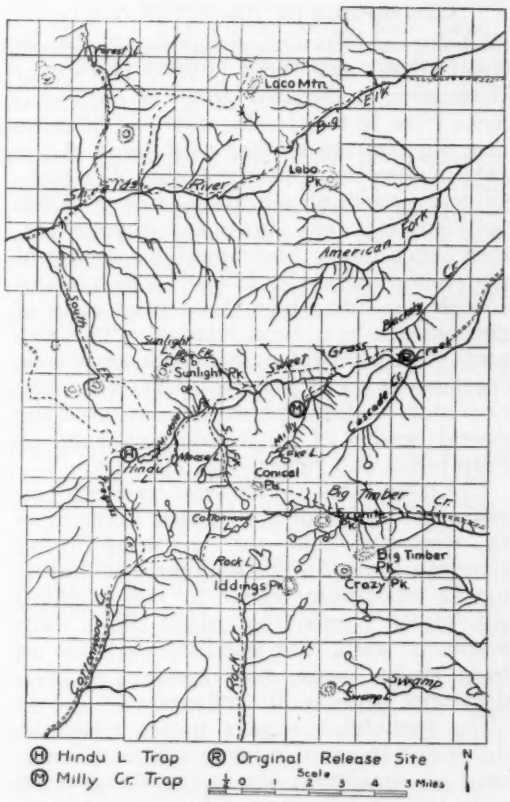

FIG. 1. Map of the Crazy Mountains.

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DESCRIPTION OF THE STUDY AREA

Geological information was obtained from Weed (1899) and Wolff (1938). The Crazy Mountains, an isolated group of connected peaks from 10 to 20 miles wide and 30 miles long, surpass most other mountains of the state in elevation and ruggedness. The highest peaks reach an elevation of over 11,000 feet, or 6,000 feet above the surrounding, open bench lands. The mountains consist of sandstones and shales of late Cretaceous or Eocene Age into which three great cores of igneous rock have been injected with thousands of associated lacoliths, sills, and dikes. The igneous rocks and sediments hardened by contact metamorphism have resisted the general erosion of the region to remain as sharp peaks and ridges (Fig. 2).

The mountains are bisected by the broad headwater valley of the Shields River flowing westward and the eastward-flowing American Fork. The highest peaks and most rugged topography occur in the southern half. Great numbers of radial dikes form prominent walls. The northern part has no sharp alpine peaks and, except for Loco Mountain, is generally timbered.

The mountains receive heavy snows in winter and frequent rains in summer, sometimes of cloudburst intensity. Many snow banks last all summer and furnish water for numerous small lakes and alpine meadows in the high basins at heads of drainages. Drainage is distinctly radial.

Although the southern portion provides excellent mountain goat habitat as demonstrated by the success of introduction, the animals apparently were never native there. The absence of goats in the ranges surrounding the Crazy Mountains and the isolated nature of the Crazy Mountains themselves probably explain this.

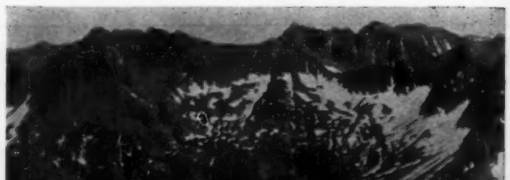

FIG. 2. Hindu Lake and summer goat range as viewed from Hindu Lake Trap. Goats were commonly seen along the ridges, in the cliffs, and in the slide rock areas. Wind blowing over the top of the ridge formed deep snowdrifts, remains of which are shown in the right side of the picture. No goats or tracks were found here in the winter.

METHODS

Two summers were spent in the mountains in immediate goat habitat. Five trips were made into the area during winter and spring. Flying for censusing and observing was done at various times throughout the year.

Two traps were constructed to live-trap goats. One was on Milly Creek, the other, five and one-half airline miles away on the main divide above Hindu Lake at the head of Sweetgrass Creek. The traps were baited with salt. The Hindu Lake trap was in operation 24 days in the summer of 1952; the Milly Creek trap eight days in the summer of 1952, 30 days in the summer of 1953. Of 21 goats trapped, 14 were marked and released, six were trap casualties; one, a kid which later died, was retained to raise for study purposes. To mark individuals, plastic ear markers of different shapes and colors (Johnson, 1951) and sheep branding paint were used. Markers were put in the right ear of goats caught at one trap and in the left ear of those caught at the other. Red paint was used at one trap; blue at the other. Large numbers and other diagnostic designs were painted on the animals.

Sex, weight, standard measurements, horn development, and condition of incisors were recorded. Three goats intentionally collected and six that died during trapping operations provided skulls and reproductive organs in addition to data procured from live specimens. A special hunting season in the fall of

1953 provided data from 22, jaws from 18, and reproductive organs from 9.

Both ground and aerial censuses were made. One ground count covering the northern half of the range was made in August, 1952, by two men traveling from north to south with horses and a light camp. Each covered a certain area each day on foot. By using binoculars, it was possible to examine much of the goat habitat.

Preliminary to an aerial count in the entire area, several flights were made to enable pilot and observer to become familiar with the area, and to locate concentrations of goats. From these flights, goat range was determined and intensive censusing was limited to Loco Mountain, Lebo Peak and the entire southern area (Fig. 1). The plane used was a 125 HP Super Cub piloted by James D. Stradley of the Gallatin Flying Service, Belgrade, Montana. The writer was the observer on all censuses.

Censusing was done by drainages. The ridge or ridges separating a drainage from areas not yet counted were flown to locate goats near the top which might move into or out of the area to be counted. The drainage was then flown at contour intervals. A rough, broken, cliffy area, or area with scrub timber, was flown at 300-foot intervals and occasionally at intervals of 100 or 200 feet if it were exceptionally rough and goats were numerous. Intervals up to 500 feet might be used above a relatively smooth shale rock or meadow type. Wider contours could be used in winter above slopes with unbroken, deep snow where no tracks were visible. Levels were held by the pilot reading the altimeter.

At times goats would stand still or even remain bedded when the plane went over. Most of them moved, however, and many tried to hide by getting under scrub timber where available, or by pressing themselves against cliffs or large rocks. They could quickly make themselves quite difficult to see. Complete aerial censuses were made in August, 1952, April, 1953, and September, 1953.

Observations were made, mostly in the Sweetgrass drainage, aided by binoculars and 20X spotting scope. Animals were approached on foot, sometimes within less than 20 feet, but usually within several hundred yards. Some observations up to two miles away were recorded. Goats were classified as adults or kids if possible. Their location, activity, habitat type, and other pertinent data were recorded. Special consideration was given to locating marked animals.

CENSUSING AND POPULATION

A comparison of the relative accuracy of ground and aerial counts is afforded by the results of censusing in about one-half the goat range by each method (Table 1). The

TABLE 1.—RESULTS OF AERIAL AND GROUND CENSUSING OF THE SAME AREA IN 1952

Date	Census Type	Total	Adults	Kids	Kid/Adult Ratio
8/ 5 to 8/12	Aerial	163	119	44	.37
8/20 to 8/25	Ground	126	83	43	.52

ground count gave only about three-fourths as many animals. The value of this comparison is lessened somewhat by the possibility of animal movements, but the kid-adult ratios suggest that some mature animals are missed by ground counts. These are possibly singles in inaccessible places.

The accuracy of aerial censusing is indicated by the results of three counts of the entire mountain goat range (Table 2). Only

TABLE 2.—RESULTS OF THREE AERIAL CENSUSES

Date	Total	Adults	Kids	Kid/Adult Ratio
8/5 to 8/12/52	252	186	66	.36
4/1 to 4/11/53	244	159	85	.54
9/1 to 9/ 6/53	278	202	76	.38

eight less goats were counted in April, 1953, than in August, 1952. Two adults had been collected between counts. The kid-adult ratio was different for the two counts, but obviously a more accurate figure was obtained in August when the young were two months old than in April when nine months old. In April, their long hair and size made it more difficult to distinguish them from adults.

Population figures obtained by the third aerial count in September, 1953, reflected a new kid crop. The number of adults counted was 202. Four adults were known to have died as a result of trapping and collecting since the last census. Evidently 38 were counted in April that were not counted in

September. Possibly some were late-winter casualties. The discrepancy may have been due to a census error resulting from a snow and rain storm during the September census period. Flying conditions were ideal the first day. The storm began that night and continued for two days. A short flight the second day of the storm indicated that the goats had moved off the high exposed ridges to lower elevations. There is positive evidence that two goats moved out of the area counted before the storm. Goats marked "8" and "10" with sheep-branding paint were seen the first day of flying and again when counting was resumed following the storm. No. 8 was alone at the edge of the counted area when first seen. He moved about 500 yards into an uncounted area. No. 10 moved about three airline miles. He was alone both times observed. These examples show that goat movements can be a source of error, but if weather permits flying every day until an area is counted, goats involved should frequently be recognized by their location and group characteristics. Snow suitable for tracking is of considerable aid. Coverage of an area without interruption should provide a reasonably accurate count. The very close agreement of the August, 1952, and April, 1953, counts strengthens this conclusion. Early-summer flying gives the most accurate kid-adult ratio (Fig. 3). It was difficult in some cases to readily distinguish kids from adults in September. The difficulty of April kid determination has been mentioned.

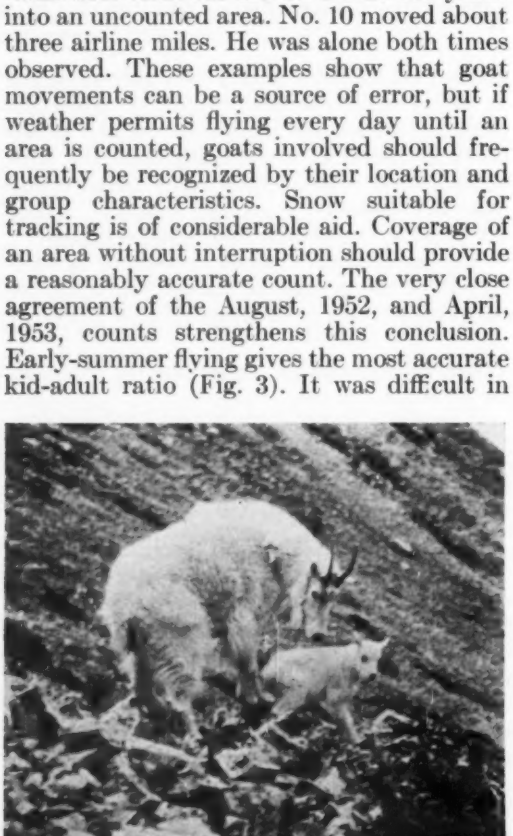

FIG. 3. Female and kid, June 19, 1952. Small kids were easy to distinguish from larger yearlings and older animals early in the summer. Their greater size and long hair made this more difficult in the winter.

REPRODUCTION

The earliest known date for new kids, May 30, 1953, was reported by fishermen. There was a gradual increase in numbers of kids seen to about June 17, after which the ratio of kids to adults was more constant. The earliest kid seen by Casebeer (1950) was on May 26, 1948. A Glacier National Park ranger is reported to have seen a kid on February 27, 1935. Anderson (1940) in Washington observed the earliest kid on May 20.

All goats seen from the ground were classified as adult or young (Table 3). Although probable yearlings were classified as such in the field, they have been included as adults. A yearling can be classified accurately only at reasonably close range and if accompanied by a kid and mature animals. The figures suggest an annual increase of about one-third.

TABLE 3.—ROCKY MOUNTAIN GOATS CLASSIFIED FROM GROUND

Date	Total	Adults	Kids	Kid/Adult Ratio
3/27/52 to 12/19/52	422	295	127	.43
2/ 2/53 to 10/11/53	788	604	184	.30
3/27/52 to 10/11/53	1210	899	311	.35

Kids were listed as triplets, twins, singles, or unclassified (Table 4). Percentage figures for classified kids should be considered minimums, as some unclassified probably fit into each category. If three stayed together and followed one adult closely, they were considered triplets.

If two kids appeared to belong to one adult they were considered twins. Numerous cases of twinning are reported by Mr. Brannin during the years previous to this study. Anderson (1940) states that in their best count in Washington, 18 nannies had one kid and three had twins. This small sample indicates that 25 per cent of the kids were twins. Casebeer (1950) states, "of 88 individual kids observed, there was evidence for only one probable case of twinning." Figures for the Crazy Mountains herd indicate a much higher rate of reproduction. Intro-

TABLE 4.—ROCKY MOUNTAIN GOAT KIDS CLASSIFIED FROM GROUND

	Triplets		Twins		Singles		Unclassified		
Date	No.	% of Total	No.	% of Total	No.	% of Total	No.	% of Total	Total
1952.....	0	0	22(44)	35	33	26	50	39	127
1953.....	3(9)	5	25(50)	27	98	53	27	15	184
1952–53.....	3(9)	3	47(94)	30	131	42	77	25	311

duction from native range in the northwestern part of the state into the possibly more fertile range of the Crazy Mountains apparently improved fertility. Cheatum and Severinghaus (1950) found in New York that white-tailed deer on good range had higher incidence of fertility and more embryos per doe than deer on poorer range.

Testes and attached epididymides from eight males and ovaries from six females were fixed in 10 per cent formalin. Portions of epididymis and testis containing seminiferous tubules from each animal were imbedded in paraffin, sectioned at 10μ, and stained with Harris' hematoxylin and eosin. Table 5 summarizes results of examinations

TABLE 5.—RESULTS OF EXAMINATIONS FOR SPERM IN EIGHT ROCKY MOUNTAIN GOATS

Date Collected	Age	Av. Wt. Testes (gms.)	Sperm Present: Seminiferous Tubules	Sperm Present: Epididymis
7/ 2	13 mo.	11.2	–	–
9/15	15½ mo.	25.3	–	–
6/10	24 mo.	16.5	–	–
9/15	39½ mo.	98.7	Devel.	–
9/27	40 mo.	149.1	+	+
6/23	4 yr.+	90.3	Devel.	–
9/21	4 yr.+	134.4	Devel.	–
9/26	4 yr.+	100.0	+	+

for sperm. Ovaries were imbedded in paraffin and serially sectioned at 15μ. All sections were saved and stained with Harris' hematoxylin and eosin. Presence or absence of corpora lutea was determined by microscopic examination (Table 6). Corpora lutea were distinguished from Graafian follicles histologically. A female with one fetus collected in March had one corpus luteum in each ovary. Of four animals taken from September 15 to October 11, three had no corpora lutea. The other, taken September 15, had one corpus luteum, indicating that she had ovulated. Cellular structure was similar to that of the corpora lutea of the pregnant female. No cellular degeneration had taken place.

TABLE 6.—RESULTS OF EXAMINATIONS FOR CORPORA LUTEA IN THE OVARIES OF SIX ROCKY MOUNTAIN GOATS

Date Collected	Age	Corpora Lutea Present
7/24.....	14 mo.	–
9/15.....	27½ mo.	1
3/22.....	34 mo.	2 (1 each ovary)
9/15.....	4 yr.+	–
9/17.....	4 yr.+	–
10/11.....	4 yr.+	–

Brandborg (1950), from direct observations in the Salmon River country of Idaho, determined that breeding occurs in November and probably continues until the middle of December. The presence of mature sperm in the epididymis and a corpus luteum in Crazy Mountains goats during September indicate that some might be capable of breeding at this time.

Presence of a corpus luteum in the 27½-month-old animal indicates fertility. Six yearling and five two-year-old females were examined (June to September). None were lactating. The pregnant female was aged at 34 months. A female aged at 38 months was lactating. The evidence indicates first breeding at approximately two and one-half years.

PHYSICAL CHARACTERS RELATED TO AGE CLASSES

Data concerning tooth development, body sizes, weights, and horn development were used to determine the most reliable and

easily used criteria for aging. After all data were considered, goats were assigned an age based chiefly on dentition. Others, including Severinghaus (1949) and Robinette and Jensen (1950), have found teeth to be reliable for aging other big game species.

TOOTH DEVELOPMENT AND REPLACEMENT—Adult mountain goat dentition consists of $I\,^0/_1\,^0/_2\,^0/_3$ $C\,^0/_1$ $PM\,^2/_2\,^3/_3\,^4/_4$ $M\,^1/_1\,^2/_2\,^3/_3$. The incisor-like lower canine is considered incisor 4 in this discussion, following the custom of many authors. The deciduous dentition consists of $DI\,^0/_1\,^0/_2\,^0/_3$ $DC\,^0/_1$ $DM\,^2/_2\,^3/_3\,^4/_4$.

Fourteen incisor examinations of six kids about three days to four months old indicated that DI_1 erupts at about seven days. $DI_{2\,3}$ were present at 14 days and DI_4 at five weeks. Each of four skulls obtained from June 25 to July 27, at ages of about one to two months, had complete deciduous premolar dentition but no molars.

Incisor development was noted for 12 goats classed as yearlings (13 to 16 months). I_1 was erupting during this period. Four yearling skulls and two lower jaws revealed all deciduous premolars. $M\,^1/_1$ were completely erupted, $M\,^2/_2$ partially erupted. Lower cheek teeth appear to come in slightly ahead of uppers.

Incisor development noted for seven animals classed as two-year-olds (24 to 28 months) indicated that I_2 begins to erupt at 24 to 25 months and is fully erupted at 28 months. Three skulls and one lower jaw indicated that permanent premolars are erupting during this period. $M\,^1/_1\,^2/_2$ were present and $M\,^3/_3$ were absent or in various stages of eruption. A goat collected in March and aged at $33\frac{1}{2}$ months had $I_{1\,2}$ $DI_{3\,4}$ $PM\,^2/_2\,^3/_3\,^4/_4$ $M\,^1/_1\,^2/_2\,^3/_3$. M^3 on each side was not fully erupted.

Incisor development was noted for eight goats classed as three-year-olds (38 to $39\frac{1}{2}$ months). Six had $I_{1\,2\,3}$ and DI_4 on both sides. One, aged at $39\frac{1}{2}$ months, differed in that I_4 on one side was starting to erupt. The incisor development of one female aged at 38 months, was typical of 26 months; i.e., $I_{1\,2}$ $DI_{3\,4}$. Her weight, measurements, and the fact that she had a kid indicated her age as 38 months. Seven three-year-old skulls each had a full complement of permanent cheek teeth. In two, both M^3 were not quite fully erupted.

Eleven goats classified as four years old or older had complete adult dentition.

These data can be applied to aging goats during fall hunting seasons. Kids have $DI_{1\,2\,3\,4}$ $DM\,^2/_2\,^3/_3\,^4/_4$. Second fall animals have I_1 $DI_{2\,3\,4}$ $DM\,^2/_2\,^3/_3\,^4/_4$ $M\,^1/_1\,^2/_2$ with $M\,^2/_2$ just erupting. By their third fall, goats have $I_{1\,2}$ $DI_{3\,4}$. Permanent premolars are replacing deciduous premolars at this time. Various combinations of deciduous and permanent premolars can possibly be expected. Milk premolars when present are badly worn. DM_4 is a three-coned tooth, PM_4, two-coned. $M\,^1/_1\,^2/_2$ are present and $M\,^3/_3$ not yet erupted or in various stages of eruption. Fourth fall animals have a full complement of permanent cheek teeth with various combinations of permanent and deciduous incisors, the most common being $I_{1\,2\,3}$ DI_4. $I_{1\,2}$ $DI_{3\,4}$ or $I_{1\,2\,3\,4}$ may also be found. Complete permanent dentition is present in succeeding years.

Casebeer (1950) obtained 18 incisor and eight cheek teeth observations from goats less than four years old, in May and June, a month earlier than the summer data and four to five months earlier than the hunting season data of this study. Similar tooth development and replacement for the two herds is indicated. The two sets of data can be combined without conflict.

BODY WEIGHTS AND MEASUREMENTS—Two males, captured when about three days old, were held by Mr. Brannin for study. They were with the nanny when caught but were not too active. A man walking could keep up with them. Their hooves were still soft, their umbilical cords reddish, somewhat translucent, and about six inches long. Twice a day an Angora goat was held so they could nurse and twice a day they were fed six ounces of Angora milk from a bottle. They were quite active after a week. One died at five weeks apparently due to fence injuries and possibly from injuries inflicted by an Angora nanny. The other became sick and died after six months. The captives weighed 6.25 and 6.50 pounds when captured. At 14 days each weighed 9.75 pounds. Standard measurements (total length, tail, hind foot, and ear) in inches were 24.4, 1.5, 7.1, 2.8, and 25.5, 1.8, 6.8, 2.8. Height at shoulder measurements were 15.0 inches and 14.5 inches. Eighteen weights and ten sets of measurements were obtained from the

captives and six live-trapped wild kids from June through September. These showed a progressive increase (Table 7). The oldest and largest kid, examined when four months old, was the captive still alive at that time. September data in Table 7 are from this animal. Kids approximately four months old seen at close range in the field appeared to be further developed.

Weights and measurements of goats older than kids show a gradual increase with age (Table 8). Mean and extreme weights and in general, mean and extreme measurements of each age-class were higher for males than females. This is more evident in the older groups.

Frequency distributions of weights and measurements were prepared. The age of individuals in each grouping of frequency distributions was checked by teeth. Groups suggested by weight-frequencies were kids, yearlings, two-year-olds, three- and four-year-old females, and three- and four-year-olds of either sex. Total length, hind foot, and height at shoulder frequencies suggested kids, yearlings, two-year-olds, and three-year-olds or older. Groups suggested by tail and ear length frequencies were kids, yearlings, and two-year-olds or older. Because of an overlap of age classes in the frequency distributions and in Table 8, weights and measurements are not considered too reliable for aging, especially beyond two years. They may be a valuable aid in aging animals that have "unusual" tooth development; e.g., retarded incisor eruption.

Casebeer obtained weights and measurements of Continental Unit goats mostly during May. Similar data from Crazy Mountains goats of the same year classes were obtained during June and July. The difference in dates prevents direct comparisons because of the possibility of additional growth and/or greater improvement of winter body condition of the later collected animals, but these factors could hardly account for the

TABLE 7.—RANGE IN WEIGHTS (POUNDS) AND MEASUREMENTS (INCHES) OF ROCKY MOUNTAIN GOAT KIDS

Month	No. of Kids	Weight	No. of Kids	Total Length	Tail	Hind Foot	Ear	Height at Shoulder
June.....	12	6.3–16.0	4	24.4–26.0	1.5–2.3	6.8–7.1	2.5–2.8	14.5–15.0
July.....	5	10.8–26.0	5	26.3–33.0	2.0–3.8	6.5–8.9	2.8–3.1	17.5–19.0
Sept.....	1	31.0	1	35.5	2.3	8.3	3.4	19.5

TABLE 8.—MEAN AND EXTREME WEIGHTS (POUNDS) AND MEASUREMENTS (INCHES) OF ROCKY MOUNTAIN GOATS FROM THE CRAZY MOUNTAINS

Estimated Age Class	Sex	No.	Weight	No.	Total Length	Tail	Hind Foot	Ear	Height at Shoulder
13 –14 mo.	F	3	67.0(62–76)	3	45.0(43.5–47.0)	3.3(2.8–4.0)	11.3(10.8–11.9)	3.9(3.8–4.0)	30.0(29.0–31.0)
13 –14 mo.	M	5	77.0(70–85)	5	47.3(36.0–51.0)	3.3(2.8–4.0)	11.2(10.9–11.5)	3.9(3.7–4.3)	31.2(30.0–35.0)
15½–16½ mo.	F	0	.....	2	48.0(47.0–49.0)	3.5(3.0–4.0)	12.0(11.5–12.5)	4.0(4.0–4.0)	32.4(30.0–34.8)
15½–16½ mo.	M	0	.....	2	52.0(51.0–53.0)	3.5(3.0–4.0)	12.3(12.0–12.5)	4.6(4.5–4.8)	35.5(34.5–36.5)
24½–26 mo.	F	2	98.0(98–98)	2	56.0(56.0–56.0)	4.0(3.0–5.0)	12.5(12.0–13.0)	4.2(4.0–4.4)	34.4(33.8–35.0)
24½ mo.	M	2	103.0(97–109)	2	56.5(47.0–66.0)	4.0(4.0–4.0)	12.9(12.8–13.0)	4.1(3.8–4.5)	32.8(30.5–35.0)
27½–28 mo.	F	0	.....	2	53.3(52.5–54.0)	4.0(4.0–4.0)	12.8(12.8–12.8)	4.4(4.4–4.5)	34.3(33.5–35.0)
33½ mo.	F	1	130.0	1	52.0	3.5	12.0	4.3	not obtained
38 mo.	F	2	124.5(124–125)	2	58.6(58.0–59.3)	4.8(4.8–4.8)	12.6(12.3–13.0)	4.3(4.3–4.4)	36.0(35.0–37.0)
39½–40½ mo.	M	2	234.0(223–245)	4	58.0(55.0–60.0)	4.8(4.0–5.8)	14.0(13.5–14.5)	4.7(4.5–4.9)	38.5(35.5–40.0)
Over 48 mo.	F	2	157.5(103–212)	5	60.8(59.0–62.5)	4.5(4.3–4.8)	12.6(12.5–12.8)	4.6(4.5–4.9)	38.8(36.5–41.5)
Over 48 mo.	M	2	180.5(151–210)	4	70.3(64.0–81.0)	4.6(3.8–5.5)	14.4(14.0–15.5)	5.0(4.5–5.6)	42.3(39.0–45.5)

TABLE 9.—MEAN AND EXTREME WEIGHTS (POUNDS) AND MEASUREMENTS (INCHES) OF ROCKY MOUNTAIN GOATS FROM THE CONTINENTAL UNIT (FROM CASEBEER)

Estimated Age Class	Sex	No.	Weight	No.	Total Length	Tail	Hind Foot	Ear	Height at Shoulder
11–12 mo.	F	1	42.0	1	39.0	3.0	10.0	4.3	24.0
11–12 mo.	M	2	44.0(43–45)	2	37.5(37.5–37.5)	2.9(2.3–3.5)	10.4(10.3–10.5)	4.3(4.0–4.5)	24.5(24.0–25.0)
23–24 mo.	F	1	62.0	1	46.0	4.0	11.5	4.5	32.5
23–24 mo.	M	2	62.0(57–67)	2	42.3(42.0–42.5)	2.6(2.5–2.8)	11.0(10.5–11.5)	3.7(3.3–4.0)	27.3(24.5–30.0)
35 mo.	F	2	104.5(101–110)	2	53.5(53.0–54.0)	4.8(4.5–5.0)	12.5(12.5–12.5)	4.6(4.5–4.8)	32.9(32.3–33.5)
35 mo.	M	1	102.0	2	51.8(49.0–54.5)	4.1(3.3–5.0)	12.4(11.8–13.0)	4.9(4.8–5.0)	35.5(35.0–36.0)
47 mo.	M	1	146.0	1	60.0	5.0	13.0	5.0	35.5

superiority in size of Crazy Mountains goats as indicated by the data in Tables 8 and 9.

Whole weights and hog-dressed weights (viscera removed) were obtained for seven animals (one two-year-old male and six three-year-old and older animals of both sexes). Average per cent of weight dressed off was 31.6. Extremes were a 24-month-old male (38.1 per cent) and a male over four taken in December (27.4 per cent). The latter had a heavy pelt, but very little fat. Goats taken during the hunting season were extremely fat. The animal thought to be the heaviest examined was a hunter-killed male over four, with a hog-dressed weight of 212 pounds. If it dressed off 31.6 per cent, whole weight would have been 310 pounds.

HORNS—Two kids approximately three days old had only the slightest of protuberances where horns would develop. After two weeks in captivity, round knobs approximately one-quarter inch high were present. Little additional growth was made by the "horns" of one captive during the summer. They measured one-quarter to three-eighths inch in September. Field observations indicated that kids' horns might be as much as an inch long at this time.

Older goats show an increase in length of outside curve and circumference at base through succeeding age classes to three years (Table 10). A greater circumference is readily apparent for males. The greatest circumference for a female was five inches; only one male two years old or older had a circumference less than five inches. Horns of males also have a greater curvature. These characteristics are poor for determining sex in the field unless one is fairly close to and familiar with the animals.

Horn measurements were placed in frequency distributions. Age of individuals was determined by teeth. Groups suggested by horn length frequencies were kids, yearlings, two-year-olds, and three-year-olds or older. Groups suggested by circumferences at base were kids, yearling females, yearling males and two-year-old or older females, and two-year-old or older males. The greater horn circumference of males is readily apparent. Although there is some overlap, data suggest that aging by horn lengths is quite accurate through two years.

June and July mean horn measurements for males and females of each year class were compared with similar data obtained in May

TABLE 10.—MEAN AND EXTREME HORN MEASUREMENTS (INCHES) OF ROCKY MOUNTAIN GOATS. INCLUDES RIGHT AND LEFT HORNS

Estimated Age Class	Sex	No. of Goats	Outside Curve	Circumference at Base
13 –14 mo.	F	3	5.3(4.9–5.9)	3.4(3.3–3.6)
13 –14 mo.	M	5	6.0(5.6–6.4)	4.3(4.1–4.5)
15½–16½ mo.	F	3	6.5(6.3–6.8)	3.8(3.5–4.0)
15½–16½ mo.	M	2	7.4(7.1–7.5)	5.0(4.8–5.3)
24½–26 mo.	F	2	7.8(7.5–8.0)	4.7(4.3–5.0)
24½ mo.	M	2	7.9(7.8–8.0)	5.3(5.1–5.5)
27½–28 mo.	F	3	8.1(7.8–8.4)	4.0(3.8–4.3)
33½ mo.	F	1	9.1(9.1–9.1)	4.0(4.0–4.0)
38 mo.	F	2	8.5(8.1–8.9)	4.5(4.2–4.8)
39½–40½ mo.	F	2	9.0(9.0–9.1)	4.5(4.5–4.5)
39½–40½ mo.	M	4	9.3(8.8–9.5)	5.3(5.0–5.5)
Over 48 mo.	F	5	9.0(8.0–9.8)	4.3(4.1–4.5)
Over 48 mo.	M	4	8.6(8.0–8.9)	5.5(5.0–5.8)

from Continental Unit animals. All but two mean measurements of Crazy Mountains goats were larger.

These data indicate that Crazy Mountains goats are larger and have earlier horn development than those of the Continental Unit studied by Casebeer. It has been suggested, under the heading "Reproduction," that introduction to new range has increased fertility. Perhaps introduction from native habitat to the possibly more fertile range of the Crazy Mountains has also caused this apparent increase in size and vigor.

PELAGE

The pelage and molt have been described for Continental Unit goats by Casebeer (1950). Crazy Mountains goats appeared to conform to the same patterns of shedding long winter hair in summer, but had longer hair. The 1953 hunting season provided skins from both areas for comparison. Hair of a 27-month-old female from the Crazy Mountains was one-half to three-quarters inch longer than hair of a 27-month-old male from the South Fork of the Flathead.

ACTIVITIES AND BEHAVIOR

GROUP SIZES AND MAKE-UP—The earliest summer field observations, starting on June 1, showed that most goats were well dispersed as small groups or singles over the kidding area. Yearlings were sometimes present with older females. Three groups of two, five, and five were observed in a small area on June 4. There were no kids. Several were thought to be yearlings. None were exceptionally large. Perhaps young, non-fertile animals band together during the parturition period. The first large group (14 kids and adults) was seen on June 15. Most goats seen during the remainder of the year were by themselves or in groups of less than ten. Group size varied during the day, and seemed to be larger late in the day. The largest group (40) was seen at dusk August 21. Groups were somewhat larger late in the winter when range was restricted. It is thought that singles were males in many cases, but mature males were also found with nannies and kids. On July 1, 15 goats, four of which were kids, were observed from less than 50 feet. Four adults stayed together. Two were large males, one was a smaller male, and the other was possibly a male.

AGGRESSIVENESS AND PLAY—On several occasions, goats displayed antagonism toward others. Females frequently charged other goats that approached their kid(s). On other occasions they were tolerant of intruders. A mature female and yearling were trapped together. The female's kid remained outside the trap. She killed the yearling by goring it in the chest cavity. On another occasion, a kid was found gored outside a trap which held another kid. A female and yearling ran from the trap site when observers approached. A large billy killed by a hunter had an apparent horn wound in the chest cavity. A hide taken from a mature male collected in December had several round scars in the rump region, possibly from horn wounds. Kids at play possibly displayed a forerunner of this type of fighting as they went round and round trying to butt each other in the rump. Kids also played by running at each other, jumping on hind legs and throwing heads into the air, or just running and jumping. They often played on snowbanks. Two kids playing together were most often twins.

WARINESS—Goats often did not display the wariness commonly associated with big game species. A concealed observer could frequently approach within close range. The animals appeared capable of detecting movement from a considerable distance but often were not alarmed. A person remaining motionless apparently was not easily discerned. When goats recognized him as something different on the landscape, they displayed curiosity and sometimes came closer or slowly circled. Goats came within 25 feet of field personnel three times in this manner; once they approached within six feet. As adult goats became curious or alarmed, they often struck the ground solidly with one of the forefeet and ran their tongues over nose and lips. Human scent left on trails and at trap sites apparently did not alarm them. They licked salt at trap sites even during periods of trap building when the area was cluttered with rolls of wire, poles, and tools. A group of goats and three mule deer were observed as they fed toward each other. They were alert as they came closer together. The deer ran off when the goats were about 30 feet away. The goats continued feeding.

BEDDING—Goats spent considerable time bedded down and were seen in beds at all times of the day. They bedded on rocks,

vegetated areas, and snow-banks. They sometimes pawed the site in soil areas with the front feet before and when lying down, so that definite beds were formed. These beds were often used by different goats, as one would get up to move or feed and another lie down. They were also used throughout the season.

SEASONAL DISTRIBUTION — During the August, 1952, April, 1953, and September, 1953, aerial censuses, 51 per cent, 66 per cent, and 57 per cent respectively, of the goats counted were in the Sweetgrass drainage or just over the ridge to the north. The increase in April was attributed to the lesser snow depth of Sweetgrass Creek as compared to Rock Creek and Cottonwood Creek, where few goats were seen. None were found in the basins at heads of eastward-flowing drainages where the west wind had carried snow over the top and deposited it in deep drifts. Goats present in deep-snow areas in the winter were found at higher elevations than generally found during the summer. It also appeared that goats ranged somewhat lower in areas of normal snow cover during the winter. Elevations, taken from the altimeter, during two censuses bear out these observations (Table 11). Goat wool lost dur-

TABLE 11.—ELEVATIONAL OCCURRENCE OF ROCKY MOUNTAIN GOATS DURING TWO CENSUS PERIODS IN 1953

Census Period	Mean and Extreme Elevations of Goats	Percent above 10,000 Feet	Percent below 9,000 Feet
4/1 to 4/11	9600(7900–10,500)	10.3	13.1
9/1 to 9/ 6	9400(8000–10,500)	2.9	11.5

ing the winter was found in the summer below timber line in the brushy bottom of Sweetgrass Creek. There was no evidence that goats came this low in the summer. Females were on lower range during the parturition period. No goats were seen in the kidding area after about July 1. No data were obtained on kids born on the higher range used throughout the year.

MOVEMENTS — Goats had distributed themselves in a semicircle with a radius of eight to ten miles from the original release site by the time of this study. This area includes most of the rougher terrain of the Crazy Mountains. Ten airline miles (Loco Mountain, head of Cottonwood Creek) was the maximum distance goats were seen from point of release (Fig. 1). A female identified by the metal stock tag in her ear as one of the original stock, was seen on Loco Mountain, July 15, 1952.

Fourteen animals were live-trapped, marked and released. Nine which were seen again provided 19 sight records (Table 12). Average distance goats were seen from where tagged was about 3 (0–8.5) miles. Average distance of first observation from where marked and subsequent from preceding observations was 2.2 miles. Data suggest different patterns of movement. Six observations of Nos. 7, 8, 38, and 13 were made as much as a year after tagging within one mile of where the animals were trapped. Five observations of Nos. 10 and 14 showed summer movements of 4.5–6 miles from the Milly Creek trap to higher elevations near the main divide. Goats 13 and 25 made summer movements of 1–1.5 miles to higher elevations on Milly Creek. Six observations of Nos. 8, 17, 9, and 25 suggested no particular pattern. No. 9, a yearling male, was seen the greatest distance from where released.

Considering animals individually gave information of movements for limited periods (Table 12). No. 8, a nine-month-old male, was seen from the air the morning of April 2, with a group of 19 goats. Their back route of probably the night before was traced north for 2.5 miles. Their tracks were followed south the next morning until the marked goat was seen 3–3.5 miles from where seen the previous day. These observations and other tracks seen during the study indicated movements during the night, mostly along ridge tops. Some were along side hills, and a few across drainages.

Eighteen of nineteen sight records of goats seen after marking were recognized by symbols or numbers applied with sheep branding paint. Paint had to be applied over old hair on animals trapped before about June 20, so was effective for approximately a month. Enough hair was usually loose after this date that it could be plucked from a small area and a symbol applied to the new coat. The largest and most easily defined symbols were painted on animals completely shed. Painting on top of the back, in addition to marking on the sides, aided in discerning marked ani-

TABLE 12.—SIGHT RECORDS OF MARKED GOATS

K, Kid; HLT, Hindu Lake Trap; MCT, Milly Creek Trap; HL, Hindu Lake; CwC, Cottonwood Creek; SlP, Sunlight Peak; MC, Milly Creek; ML, Moose Lake; SC, Swamp Creek; HBT, Head of Big Timber Creek.

Marked					Observed			
Goat No.	Sex	Age	Date	Place	Date	Location	Distance from Place Marked (airline miles)	Distance from Where Last Seen (airline miles)
7.....	M	K	7/26/52	HLT	9/25/52	HL	0.25	.....
8.....	F	K	7/26/52	HLT	9/25/52	HL	0.25	.....
					4/ 2/53	HLT	0	0.25
					4/ 3/53	CwC	3–3.5	3–3.5
					8/13/53	HLT	0	3–3.5
17.....	M	1	7/28/52	HLT	8/ 6/52	SlP	2–2.5	.....
					4/ 2/53	MC	4.5–5	4.5–5
					4/ 4/53	MC	4.5	0.75
38.....	F	4+	8/ 6/52	HLT	8/ 7/52	ML	0.25–0.5	.....
9.....	M	1	6/29/53	MCT	9/ 4/53	SC	8–8.5	.....
10.....	M	1	6/29/53	MCT	8/ 4/53	ML	4.5–5	.....
					8/ 6/53	HL	5–5.5	0.5
13.....	F	1	7/ 8/53	MCT	7/16/53	MC	1–1.5	.....
					7/23/53	MC	0.5–1	0.5
14.....	M	1	7/11/53	MCT	8/ 4/53	ML	4.5–5	.....
					9/ 1/53	ML	4.5–5	0
					9/ 5/53	HL	5.5–6	1.5
25.....	F	2	7/23/53	MCT	9/ 1/53	MC	1–1.5	.....
					9/ 4/53	HBT	3.5–4	3

mals from the air. Red symbols were more easily defined than blue. Paint was distinct on two goats after eight months. One animal was recognized more than a year after tagging by its plastic ear marker. Due to positions assumed by head and ears of goats, a plastic marker fastened to the inside surface of the ear is more visible than one on the back of the ear.

MOISTURE REQUIREMENTS

Snow and snow water close to the snow banks probably furnished most of the moisture required by goats. As snow at lower elevations melted in the spring, goats were found higher closely associated with the "permanent" snow banks. They sometimes bedded, played, and walked on these banks and occasionally appeared to eat snow. Snow banks were so numerous that most goats seen during the summer were less than 500 yards from snow. Also during the summer, several instances of goats drinking in streams were noted and tracks were seen around some of the lakes.

ADVERSE FACTORS

Remains of three dead goats all less than four years old were found. Cause of mortality was not known. One could have been killed by a snow-slide; one had been washed down Milly Creek, possibly after death; one represented by a portion of skull and the horns had evidently been found and placed along the trail. Snowslides were a possible cause of mortality as goats were seen in snowslide areas during the winter. The only instance of a goat actually losing its balance

was noted in August when a kid slid down a 50-foot snowbank but recovered its balance in the rock slide at the bottom. Golden eagles were frequently seen in goat habitat but goats rarely paid any attention to them. Occasionally an adult would look up when an eagle flew over. Only one case of an eagle molesting goats was noted. During aerial observations on March 7, 1952, an eagle was seen diving at seven goats (four adults, three young) which had already been frightened by the plane. The eagle left when chased by the plane. Casebeer stated that most natural losses occurred in winter when weather enhanced susceptibility to predators, parasites, diseases, and accidents. He lists eagles as probably the most important predators and cites several cases of eagles preying on goats. A female with a large red sore on her throat was seen in the Crazy Mountains late in June. Casebeer mentioned reddish-hued patches on throat and neck in May, possibly due to excrement from ticks. Injuries inflicted on goats by each other have been discussed under the heading "Aggressiveness."

LONGEVITY

A female identified as of the original stock by her metal ear tag was seen July 15, 1952. If released in 1941, her minimum age was 12 years; if released in 1943, minimum age was 10 years. She was possibly older as only one of six females released in 1941 and one of seven released in 1943 were yearlings.

SUMMARY

1. A mountain goat herd originating from 21 animals released in the Crazy Mountains, southwestern Montana, in 1941 and 1943, was studied from March, 1952, to October, 1953. The Crazy Mountains are among the highest and most rugged in the state.

2. Two methods, ground and aerial, were used for censusing. Censusing was done by working from one end of the range to the other as rapidly as possible. Aerial counts were made by flying a drainage at contour intervals of from generally 300 to 500 feet.

3. Kid-adult ratios of ground and aerial counts suggest that some mature animals were missed during the ground count. In aerial censusing, the most accurate kid-adult ratios were obtained during the summer. Snow, suitable for tracking, was an aid in winter censusing. The largest total count, 278, was obtained by an aerial census in September, 1953.

4. The earliest date reported for new kids was May 30. No new kids were recognized after June 17.

5. Kid-adult ratios suggest an annual increase of about one-third.

6. Six cases of probable triplets were seen during the study. Of all kids classified from the ground, 3 per cent were triplets, 30 per cent were twins, 42 per cent were singles, and 25 per cent were not classified.

7. Testes from eight males and ovaries from six females were collected. The presence of sperm in the epididymis of two males and a corpus luteum in the ovary of one female in September-killed animals indicated that these animals might be capable of successfully breeding at this time. The female with a corpus luteum was about $27\frac{1}{2}$ months old. Two-year-old females examined were not lactating. A female aged at 34 months was pregnant. A three-year-old female was lactating. These data indicate that females first breed when approximately two and one-half years old.

8. Live-trapping, collecting, and examining hunter-killed animals gave data on dentition, weights, body measurements, and horns.

9. Tooth development and replacement appeared to be the best criteria for aging. Yearly age classes were established to four years.

10. Weights, body measurements, and horns indicate that goats from the Crazy Mountains are larger than those from the Continental Unit. Crazy Mountains goats appear to have longer hair than Continental Unit animals.

11. Females generally did not tolerate other goats close to their kids. Goats often were not too wary and could be closely approached.

12. Goats appeared to move from deep snow areas to lesser snow areas during the winter. More were found above 10,000 feet and below 9,000 feet during the winter than during the summer. Females and younger animals were dispersed and at lower elevations during the parturition period.

13. Goats had distributed themselves over most of the rough area of the Crazy Mountains in the 11 years following introduction. Ten airline miles was the maximum distance they were found from the original release site.

14. Sight records of animals which had been live-trapped, marked, and released gave information on movements. Six observations of four were made within a mile of where trapped. Five observations of two indicated summer movements of 4.5–6 miles to higher range. Six observations of four suggested no particular pattern. Considering animals individually gave information of movements for limited periods.

15. Eighteen sight records were obtained by recognizing numbers or symbols painted on the hair with sheep-branding paint. Two were obtained after eight months. One sight record, made a year after tagging, was procured by recognition of a plastic ear marker.

16. Other observations of activities and behavior, pelage, moisture requirements, and adverse factors are described.

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FOOD HABITS AND RANGE USE OF THE ROCKY MOUNTAIN GOAT IN THE CRAZY MOUNTAINS, MONTANA[1]

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An investigation of a transplanted Rocky Mountain goat (*Oreamnos americana missoulae*) herd was conducted in the Crazy Mountains, Montana during 1952 and 1953. The history of the herd, biological data concerning the goats, and a general description of the area have been reported by Lentfer (1955). The author worked in conjunction with Lentfer, but concentrated on the food habits and range use.

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METHODS

During the spring, summer and fall of 1952 and 1953, plants in the vegetative types frequented by goats were collected for use as reference specimens in the identification of food items. Scientific and common names

follow Booth (1950), and Wright and Booth (1954). In cases where these authors did not cite common names, those given by the American Joint Committee on Horticultural Nomenclature (1942) or Sampson (1952) are used.

Seven 100-ft. line transects (two in alpine meadows, three on slide rock slopes, one on a ridge top, and one in the timber) provided a sample of the plants present. The author recognizes the limitations of the sampling, but believes the data warrant inclusion. A 100-ft. cord was stretched out on the vegetative type, and the basal intercept of each plant was measured, similar to the method described by Canfield (1941). Instances of animal use on these plants were also recorded.

A total of 149 days was spent in goat habitat: 24 in spring (June), 94 in summer (July and August), 21 in fall (September), and 10 in winter (December and March). Spring, summer and fall travel within the area was usually on horseback. When possible, close observations of goats were made on foot. Winter travel required the use of snowshoes. The animals were approached as closely as possible, sometimes to a distance of 100–200 yards, but the majority of goats seen were at greater distances. One was observed at six feet. A total of 1262 goat observations were recorded, 795 of feeding goats. Information was recorded on time of day seen, on vegetative type utilized, and on the plant species fed upon, when possible. Early in the study an attempt was made to evaluate the latter on the basis of "animal minutes" of feeding on individual plants, after the procedure of Cowan (1947) and Beuchner (1950). This method was abandoned. Observations were made with 7-power binoculars and a 20-power spotting scope. Even at distances of 10–100 yards, it was usually impossible to identify the individual plant species being utilized. A follow-up method was used by Brazda (1953) on elk was adopted. The area where feeding occurred was closely examined and plants utilized were recorded.

Twenty-seven stomach samples were obtained: three from intentionally collected animals, six from trap casualties, and 18 from hunter-killed goats. The monthly sequence was: 2 in June, 5 in July, 14 in September, 4 in October, and one each in December and March. The samples were preserved in 10 per cent formalin as soon as possible after collection.

Stomach analyses were performed in the laboratory. Volumes of the samples were determined by water displacement, after the excess moisture was removed by squeezing on paper towels. The average volume of 19 samples was 218 cc. Each sample was washed on a 4-mm. mesh screen in a specimen pan. The material which passed through was collected on a one-mm. mesh screen and retained as unidentifiable. The material on the 4-mm. mesh screen was then emptied into the pan and flooded with water. Recognizable plant parts were removed with forceps and placed in dishes for comparison with reference specimens. With the use of a binocular microscope, identification to species was possible in most instances. Plant volumes were determined by water displacement. This material was then air dried, and weights were determined to the nearest hundredth-gram. The unidentifiable component from the 4-mm. screen was combined with that from the one-mm. screen, and the volume and weight were determined. The average percentage of weights and volumes of the unidentifiable material was 65.4 and 70.9 respectively.

Smith (1952), studying food habits of mule deer in Utah, used weight-estimate and ocular - estimate - by - plot methods supplemented by a modified volume - by - weight method. This was considered for the present study, but alpine vegetation, because of its low growth form, did not lend itself to this procedure.

Several exclosures were set up in feeding areas for comparison with similar unprotected plots (Beruldsen and Morgan, 1934), but this method was discontinued. It was thought that a comparison of the weights of clipped plants from each, following a seasonal feeding period, would reveal food preferences. The rocky nature of the feeding areas made it difficult to select plots of equal size relative to vegetative cover. A large number of plots would be required to reduce this error. Time required for such extensive construction of exclosures was not available.

GENERAL VEGETATIVE TYPES

The area below 9000 ft. is a timber type made up of limber pine (*Pinus flexilis*) or whitebark pine (*Pinus albicaulis*) and alpine fir (*Abies lasiocarpa*) interspersed with

Douglas fir (*Pseudotsuga taxifolia*) and Engelmann spruce (*Picea engelmanni*) (Fig. 1). The vegetation of the forest floor is predominantly dwarf huckleberry (*Vaccinium scoparium*), elk sedge (*Carex geyeri*), and Ross sedge (*Carex rossii*).

FIG. 1. Timber type below 9000 feet and grassy slide-rock slopes above timberline.

Above timberline, there are grassy slide-rock slopes and cliffs characterized by alpine bluegrass (*Poa alpina*), skyline bluegrass (*Poa epilis*), timberline bluegrass (*Poa rupicola*), tufted hair grass (*Deschampsia caespitosa*), spreading wheat grass (*Agropyron scribneri*), and another wheatgrass (*Agropyron latiglume*) (Fig. 1). The most abundant dicotyledonous plants are field chickweed (*Cerastium arvense*), yellow stonecrop (*Sedum stenopetalum*), lupine (*Lupinus monticola*), cinquefoil (*Potentilla* sp.), and polemonium (*Polemonium pulcherimum*). Much of the vegetation is underlain with moss (*Polytrichum* sp.) and yellow dot saxifrage (*Saxifraga bronchialis*).

The ridge tops, commonly at 10,000 to 11,000 ft., are rocky. The vegetation is alpine. Predominant grasses are alpine bluegrass, timberline bluegrass, and spike trisetum (*Trisetum spicatum*). The sedges and rushes include *Carex atrosquama*, *Carex scopulorum*, and *Luzula spicata*. The important dicotyledonous plants are lupine, moss silene (*Silene acaulis*), Nuttall's sandwort (*Arenaria nuttallii*), cinquefoil, and field chickweed.

Small alpine meadows are present below semi-permanent snow drifts and on other moist areas. The rushes, *Juncus parryi*, *Juncus regelii* and *Luzula spicata* are the most abundant plants. Important sedges and grasses are *Carex phaeocephala*, *Carex engelmannii*, tufted hair grass, bent grass (*Agrostis humilis*), and alpine bluegrass. Dense, isolated stands of bluebells (*Mertensia ciliata*), goldenrod (*Solidago multiradiata*), and butterweeds (*Senecio crassulus* and *Senecio triangularis*) are also present. White heather (*Cassiope mertensiana*), mountain heath (*Phyllodoce empetriformis*), swamp laurel (*Kalmia polifolia*), and dwarf huckleberry are also abundant. This vegetative type is almost entirely underlain by moss.

RESULTS

FEEDING PERIODS — Records of feeding goats observed are given in Table 1. The data indicate feeding throughout the day with peaks suggested in early morning and evening. The number of observations during these periods was less than for the remainder of the day. No change was observed in this pattern during the spring, summer or fall. During the winter, 19 mountain goats were observed from the ground, all between 11:00 A.M. and 4:30 P.M. Twelve were feeding.

USE OF VEGETATIVE TYPES FOR FEEDING—Timbered types received little use as feeding areas from June through September. Only 61 of 783 feeding mountain goats, observed during this period for the two years, were in this type. Spring utilization ap-

TABLE 1.—NUMBER OF ROCKY MOUNTAIN GOATS OBSERVED, AND NUMBER OBSERVED FEEDING DURING SPRING, SUMMER AND FALL, 1952–1953

Hours	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9
Animals Observed	6	10	12	47	127	146	32	149	161	68	151	125	134	56	8	11
Animals Feeding	6	9	11	17	62	57	16	50	105	60	113	111	98	49	8	11
Percent Feeding	100	90	92	36	49	39	50	34	65	88	75	89	73	88	100	100

peared to be by nannies during the parturition period. Summer and fall use was usually by single animals or groups of less than five. These appeared to be adult males. Food habits discussed later suggest use in winter.

Grassy slide-rock slopes were the major feeding areas during spring, summer and fall, as indicated by 422 animals observed grazing in the type. Many of these slopes were found to be blown free of snow in December and March. Seven of the 12 feeding goats observed in winter were on this type.

Ridge tops were next in importance. Records show 133 goats feeding in this type, June through September. This type is often snow-free in winter due to strong westerly winds, suggesting that it may be an important grazing area at that time.

Most alpine meadows are covered by snow drifts well into July. They become verdant as the snow recedes and remain lush until late fall. One hundred twenty-five animals were observed feeding here, principally in August and September.

Vegetation on cliffs is sparse, only 42 goats were observed grazing in this type.

FOOD HABITS—Direct observations suggest that mountain goats are "snip-feeders," rarely grazing intently on any particular spot. Occasionally they graze off nearly all the flower stalks of mountain bluebell and butterweed patches. A wide variety of forage plants was utilized, particularly during summer and fall (Table 2). Examination of feed-

TABLE 2.—AVERAGE ABUNDANCE OF HERBACEOUS PLANTS ALONG SEVEN 100-FT. LINE TRANSECTS IN FOUR VEGETATIVE TYPES, AND MOUNTAIN GOAT USAGE OF SPECIES AS DETERMINED BY EXAMINATION OF FEEDING AREAS AND STOMACH ANALYSES

Plants	Transects Summer Comp. (%)	Obs. Summer Use Freq.	Stomach Analyses							
			Summer-5		Fall-18		Winter-2		Spring-2	
			% Vol.	% Wt.	% Vol.	% Wt.	% Vol.	% Wt.	% Vol.	% Wt.
Grasses, Sedges, Rushes	45.1	425	71.7	75.5	76.2	74.7	59.1	58.8	70.4	75.8
Graminae	..	..	x[1]		..	..	..	..	x	
Agropyron latiglume	2.2	13	x		x		..	..	..	..
Agropyron scribneri	2.2	19	x		x		..	..	..	..
Agropyron spicatum	..	..	x		..	..	..	..	..	..
Agropyron subsecundum	0.6	6	..	..	x		..	..	..	..
Agrostis humilus	0.1	2	..	..	..	..	..	..	..	..
Agrostis scabra	..	15	x		x		..	..	..	..
Calamagrostis canadensis	..	..	..	..	x		..	..	..	..
Danthonia intermedia	..	..	..	..	x		..	..	..	..
Deschampsia atropurpurea	tr	17	..	..	x		..	..	..	..
Deschampsia caespitosa	4.7	27	x		x		..	..	..	..
Festuca idahoensis	..	..	..	..	x		..	..	..	..
Festuca ovina	4.0	27	x		x		..	..	..	..
Phleum alpinum	0.2	1	..	..	x		..	..	x	
Poa alpina	4.3	47	x		x		..	..	x	
Poa arctica	0.7	4	..	..	..	..	..	..	..	..
Poa cusickii	..	..	x		x		..	..	..	..
Poa epilis	6.6	12	x		..	..	..	..	..	..
Poa fendleriana	..	6	..	..	..	..	..	..	..	..
Poa pattersoni	..	..	x		x		..	..	..	..
Poa rupicola	2.0	40	x		x		..	..	..	..
Trisetum spicatum	1.3	18	..	..	x		..	..	..	..
Trisetum wolfii	..	..	..	..	x		..	..	..	..
Carex atrosquama	4.1	30	..	..	..	..	..	..	..	..
Carex engelmanii	tr	..	..	..	..	..	..	..	x	
Carex festivella	0.2	5	..	..	x		..	..	..	..
Carex geyeri	..	5	..	..	..	..	..	..	x	
Carex hepburnii	..	2	..	..	..	..	..	..	..	..

[1] "x" denotes identification of the plant in the stomachs.

TABLE 2.—(Continued)

Plants	Transects Summer Comp. (%)	Obs. Summer Use Freq.	Stomach Analyses							
			Summer-5		Fall-18		Winter-2		Spring-2	
			% Vol.	% Wt.	% Vol.	% Wt.	% Vol.	% Wt.	% Vol.	% Wt.
Carex pachystachya	0.7	8	..	..	..	..	..	..	..	..
Carex phaeocephala	1.0	6	..	..	x		..	..	x	
Carex rossii	0.4	..	..	..	..	..	..	..	..	..
Carex sp.	..	..	x		x		x		x	
Juncus parryi	3.4	37	x		x		..	..	..	..
Juncus regelii	1.9	31	..	..	x		..	..	..	..
Luzula parviflora	0.4	10	..	..	x		..	..	..	..
Luzula spicata	4.0	37	x		x		x		..	..
Forbs	30.4	189	17.2	13.9	19.9	21.5	15.8	10.4	13.1	4.8
Achillea lanulosa	0.9	..	..	..	0.4	0.5	tr	tr	tr	tr
Acteae arguta	tr	2	..	..	..	..	..	..	..	..
Agoseris glauca	..	..	..	..	0.1	0.1	..	..	..	..
Allium cernuum	..	9	..	..	..	..	..	..	tr	tr
Antennaria media	0.2	2	..	..	..	..	..	..	..	..
Arabis glabra	tr	..	..	..	..	..	..	..	..	..
Arenaria congesta	..	..	..	..	tr	0.1	..	..	..	..
Arenaria nuttallii	1.3	..	..	..	..	..	..	..	..	..
Arnica cordifolia	0.7	6	..	..	tr	tr	..	..	..	..
Astragulus alpinus	0.7	..	..	..	tr	0.1	..	..	..	..
Besseya cinera	0.4	3	tr	tr	tr	tr	..	..	tr	tr
Campanula rotundifolia	..	..	..	..	tr	tr	..	..	..	..
Castelleja pulchella	0.1	..	..	..	..	..	..	..	..	..
Cerastium arvense	4.6	5	1.3	0.6	0.4	0.5	tr	tr	tr	tr
Cirsium sp.	..	..	..	..	tr	tr	..	..	..	..
Clematis tenuiloba	1.1	7	..	..	..	..	..	..	..	..
Delphinium bicolor	..	8	..	..	..	..	..	..	..	..
Douglasia montana	0.3	..	..	..	..	..	..	..	..	..
Draba incerta	0.4	..	..	..	..	..	..	..	..	..
Erigeron compositus	0.2	3	..	..	tr	tr	..	..	..	..
Erigeron formosissimus	0.1	..	..	..	tr	tr	..	..	..	..
Erigeron rydbergii	0.1	1	..	..	..	..	..	..	..	..
Erigeron simplex	0.4	..	tr	tr	tr	tr	..	..	..	..
Eriogonum flavum	..	7	tr	tr	tr	tr	..	..	tr	tr
Eriogonum ovalifolium	..	..	..	..	tr	tr	14.1	8.4	..	..
Frasera speciosa	0.1	7	..	..	..	..	..	..	..	..
Galium boreale	0.0	..	0.9	0.5	tr	0.1	..	..	..	..
Hedysarum sulphurescens	..	6	3.4	1.0	tr	0.5	..	..	..	..
Heracleum lanatum	..	..	..	..	4.0	3.6	..	..	..	..
Heuchera ovalifolia	..	..	tr	tr	tr	tr	..	..	2.7	1.5
Hieracium gracile	0.1	..	..	..	..	..	..	..	..	..
Hulsea carnosa	..	6	..	..	..	..	..	..	..	..
Lomatium foeniculaceum	0.5	..	..	..	tr	tr	..	..	..	..
Lupinus monticola	2.2	22	tr	tr	2.0	2.0	..	..	..	..
Mertensia ciliata	0.5	24	1.2	3.2	2.6	2.7	..	..	..	..
Oxyria digna	..	..	..	..	tr	tr	..	..	..	..
Oxytropis sp.	0.2	..	..	..	..	..	..	..	..	..
Oxytropis sericea	0.2	..	..	..	..	..	1.7	0.9	..	..
Pedicularis groenlandica	tr	4	..	..	..	..	..	..	..	..
Pentstemon attenuatus	..	..	..	..	tr	tr	..	..	..	..
Pentstemon procerus	..	..	..	..	0.3	0.5	..	..	..	..
Phacelia serecia	..	7	..	..	..	..	..	..	..	..
Polemonium pulcherimum	1.7	17	tr	tr	1.2	1.1	..	..	tr	tr
Polygonum bistortoides	tr	..	2.5	2.5	tr	tr	..	..	..	..
Polygonum viviparum	..	..	tr	tr	tr	tr	..	..	..	..

TABLE 2.—(Continued)

Plants	Transects Summer Comp. (%)	Obs. Summer Use Freq.	Stomach Analyses							
			Summer-5		Fall-18		Winter-2		Spring-2	
			% Vol.	% Wt.	% Vol.	% Wt.	% Vol.	% Wt.	% Vol.	% Wt.
Potentilla sp.	1.6	..	..	..	tr	tr	tr	tr	..	..
Potentilla diversifolia	tr	..	5.2	4.1	tr	0.6	..	..	..	..
Potentilla glandulosa	..	..	..	..	0.6	0.6	..	..	..	..
Potentilla multisecta	0.4	..	..	..	0.1	0.3	..	..	10.4	3.3
Potentilla nivea	0.9	..	..	..	tr	tr	..	..	..	..
Saxifraga bronchialis	1.4	3	tr	tr	0.1	0.2	tr	tr	..	..
Saxifraga montanensis	0.3	4	..	..	..	..	..	..	..	..
Saxifraga punctata	..	..	tr	tr	tr	tr	..	..	..	..
Sedum stenopetalum	2.1	1	..	..	tr	tr	..	..	..	..
Senecio crassulus	tr	..	..	..	3.0	2.6	..	..	..	..
Senecio fremontii	tr	..	..	..	..	..	..	..	..	..
Senecio residifolius	tr	..	..	..	..	..	..	..	..	..
Senecio saxosus	0.4	4	..	..	..	..	..	..	..	..
Senecio triangularis	tr	7	..	..	4.0	3.3	..	..	..	..
Silene acaulis	4.4	..	..	..	tr	tr	..	..	..	..
Smilacina racemosa	0.3	3	..	..	..	..	..	..	..	..
Solidago sp.	..	..	..	..	0.2	0.2	..	..	..	..
Solidago multiradiata	0.3	10	..	..	0.8	0.8	..	..	..	..
Syntheris dissecta	0.3	..	..	..	tr	tr	..	..	..	..
Taraxacum laevigatum	..	..	..	..	..	..	..	..	tr	tr
Thalictrum dasycarpum	0.9	10	tr	tr	..	..	..	..	..	..
Townsendia parryi	..	..	..	..	tr	tr	..	..	..	..
Veronica wormskjoldii	0.2	1	..	..	tr	tr	..	..	..	..
Unidentified Forbs	..	..	2.7	2.0	1.0	1.1	tr	1.1	tr	tr
Shrubs	22.3	124	3.3	2.0	0.7	1.2	tr	tr	0.9	1.2
Apocynum androsaemifolium	..	..	..	..	tr	tr	..	..	..	..
Artemesia michauxiana	tr	6	tr	tr	tr	tr	tr	tr	..	..
Cassiope mertensiana	2.6	8	tr	tr	tr	tr	..	..	..	..
Ceanothus velutinus	..	2	tr	tr	..	..	..	..	..	..
Kalmia polifolia	0.3	..	..	..	..	..	..	..	..	..
Pentstemon fruiticosus	..	..	..	..	..	..	..	..	0.9	1.2
Phyllodoce empetriformis	0.5	16	..	..	..	..	..	..	..	..
Potentilla fruiticosa	0.5	14	..	..	..	..	..	..	tr	tr
Ribes lacustre	tr	17	tr	tr	tr	tr	..	..	tr	tr
Rubus idaeus	0.5	..	..	..	..	..	..	..	..	..
Salix sp.	5.7	22	tr	0.3	0.6	0.9	..	..	tr	tr
Vaccinium membranaceum	0.5	5	..	..	..	..	..	..	..	..
Vaccinium scoparium	11.7	34	3.3	1.7	0.1	0.3	..	..	..	..
Coniferous trees	..	26	tr	1.1	tr	tr	24.6	30.4	12.7	17.9
Juniperus communis	..	9	..	..	..	..	1.2	1.9	tr	tr
Juniperus scopulorum	..	1	..	..	..	..				
Pinus albicaulis or *Pinus flexilis*	..	11	tr	1.1	tr	tr	tr	tr	2.7	2.4
Pseudotsuga taxifolia	..	2	..	..	tr	tr	23.4	28.5	10.0	15.5
Abies lasiocarpa	..	3								
Deciduous Trees	..	..	..	..	..	..	..	..	..	..
Populus tremuloides	..	2	..	..	..	..	..	..	..	..
Mosses, Lichens, Ferns	..	..	3.2	4.5	tr	tr	tr	tr	0.9	tr
Polytrichum sp.	tr	..	tr	tr	tr	tr	tr	tr	tr	tr
Crutose lichens	tr	..	tr	tr	tr	tr	tr	tr	0.9	tr
Woodsia scopulina	tr	..	3.2	4.5	..	..	tr	tr	..	..
Total		766								

ing areas and stomach analysis indicated that the following plant parts were utilized: foliage and seed heads of grasses, sedges and rushes; foliage, stems and flowers of forbs; leaves and twigs of shrubs and trees; leaves of ferns; and the entire aerial part of mosses and lichens. Kids about one month old were observed grazing with adults as early as June 28. The stomach from a kid (trap casualty) collected July 10, 1953, contained fern, flower heads, seed heads from grasses, sedges, and rushes, and a few milk curds. This may indicate that young mountain goats choose tops of succulent plants on their first attempts at grazing. Captive kids were observed to feed in a similar manner.

Summer—Examination of feeding areas in summer indicated that 56 per cent of the plants taken were grasses, sedges and rushes. Mule deer may have accounted for some of this use at lower elevations. The species used most frequently were tufted hair grass, sheep fesque (*Festuca ovina*), alpine bluegrass, timberline bluegrass, sedge (*Carex atrosquama*), and rushes (*Juncus parryi, Juncus regelii* and *Luzula spicata*). All except one appeared in stomach samples (Table 2). Grasses, sedges and rushes constituted 71.7 per cent of the volume and 75.5 per cent of the weight of the contents of five stomachs. Individual species of this group were commonly recognized in the stomach samples, but it was impractical to separate each for quantitative measurements. A complete list of plants concerned in the food habits evaluation is given in Table 2.

Forbs made up 24 per cent of the grazed plants observed on feeding areas. Lupine, mountain bluebells, and polemonium had been utilized most frequently. These plants, plus sweet vetch (*Hedysarum sulphurescens*), bistort (*Polygonum bistortoides*), and cinquefoil (*Potentilla diversifolia*) constituted the greatest volume or weight of forbs in stomachs. Forbs formed 17.2 per cent of the volume and 13.9 per cent of the weight of the material identified in summer stomachs.

Sixteen percent of the observed use was on shrubs. Dwarf huckleberry, willow (*Salix* sp.), swamp currant (*Ribes lacustre*), mountain heath and shrubby cinquefoil (*Potentilla fruiticosa*) were the principal plants recorded. All except the latter two species were present in stomachs. *Vaccinium scoparium* was the most important. Shrubs composed 3.3 and 2.0 per cent of the volume and weight respectively.

Coniferous and deciduous trees made up less than 4 per cent of the use detected on examination of feeding areas. Pine and juniper (*Juniperus communis*) received the most use. This class was relatively unimportant in the stomachs. Dry pine needles were present in the stomachs from all seasons. These may have been picked up incidental to other feeding.

Use of mosses, lichens and ferns was not recognized on feeding areas. They were all present in summer stomachs (vol. 3.2 and wt. 4.5 per cent), but fern (*Woodsia scopulina*) was the most important, chiefly because of the kid stomach mentioned previously.

Fall — The numbers of observations on feeding sites in fall, winter and spring were too few for consideration. Only stomach analyses are available for food habits evaluation. Grasses, sedges and rushes composed 76.2 per cent of the volume and 74.7 per cent of the weight of the contents of 18 stomachs. Most of the species identified in summer stomachs were present in stomachs of this season, and in addition several more were recognized, possibly because seed heads were more easily identified in fall.

Forbs increased from 17.2 per cent of the volume and 13.9 per cent of the weight in summer stomach contents to 19.9 and 21.5 per cent in fall stomachs. Coincident with this increase in volume and weight was an increase in the number of species. These included the plants commonly found in summer stomachs. Species occurring in considerable amounts in fall stomachs only, were cow parsnip (*Heracleum lanatum*) and butterweeds.

Shrubs decreased in volume and weight from that found in summer (Table 2). Species in fall stomachs were in general the same as those in summer stomachs. Percentages of *Vaccinium scoparium* decreased; *Salix* increased slightly; and the others remained about the same.

Coniferous trees, mosses and lichens changed little in importance from summer to fall. It is notable that Douglas fir and/or alpine fir which was used most often in winter, appeared first in a stomach collected about the middle of October. Mosses (*Polytrichum* sp.) and crustose lichens were pres-

ent only as traces. *Woodsia scopulina*, which was important in summer stomachs, was not found in stomachs from this season.

Winter—Grasses, sedges and rushes in two stomachs decreased when compared with summer or fall (Table 2). With two exceptions, plants were identifiable to family only.

Forbs represented 15.8 per cent of the volume and 10.4 per cent of the weight of the stomach contents. Only a few species were represented. Cushion eriogonum (*Eriogonum ovalifolium*), which made up the principal part of the volume or weight of this class, and white pointloco (*Oxytropis sericea*) were the only forbs occurring in significant amounts in the winter stomach samples.

Shrubs were an unimportant plant class. They were represented only by Michaux sage (*Artemesia michauxiana*).

Coniferous trees formed 24.6 per cent of the volume and 30.4 per cent of the weight of the samples. This class of plants was found most commonly during winter. Douglas fir and/or alpine fir (indistinguishable) made up most of this volume or weight. Juniper and pine constituted only a small part of the samples.

Mosses, lichens and ferns were present as traces.

Spring—Grasses, sedges and rushes increased in volume and weight, as compared to winter, the number of species identified remained low. Volumes and weights are similar to those for summer and fall (Table 2).

The number of species of forbs recognized was greater than in the winter, but fewer than in summer or fall. Two plants, alumroot (*Heuchra ovalifolia*) and cinquefoil (*Potentilla multisecta*) made up most of the volume or weight. These two plants were more abundant in stomach samples for this season than any other.

Shrubs were present in relatively small amounts as in winter. Desert mountain pentstemon (*Pentstemon fruiticosus*), the most prominent, was identified only in spring stomachs.

Coniferous trees decreased in relative volume and weight from winter, but was still a major item. Douglas fir and/or alpine fir were the most outstanding of this group. As was noted in winter, pine was less important, but made up a higher percentage in this season than in any other. Some green pine needles were recognized as part of this component.

Mosses, lichens, and ferns were an insignificant part of these stomach samples, with crustose lichens the most important.

The data indicate that grasses, sedges, and rushes were taken more commonly than any other class of plants during all seasons. Forbs were next in importance in summer and fall, but third in winter and spring. Coniferous trees were second in winter and spring, but unimportant in summer and fall. Shrubs were third in summer and fall, and fourth in winter and spring. Mosses, lichens and ferns were minor items during all seasons. Casebeer, *et al.* (1950), working in the Continental Divide area, Montana, and Anderson (1940), in Washington, have stated that shrubs, grasses and forbs ranked in that order as mountain goat foods in summer. In winter, Casebeer found that grasses and shrubs were the major items. Anderson found grasses to be most important in winter. Swift (1940) in the Black Hills, South Dakota, observed use of aspen and birch in spring and summer, but lichens, grasses and other herbaceous material in fall. Harmon (1944), also in the Black Hills, South Dakota, found moss and lichen, bearberry, pine and miscellaneous vegetation as the forage used in winter.

SUMMARY

1. The food habits and range use of an introduced mountain goat herd in the Crazy Mountains, Montana were studied during 1952–1953.

2. Plants from the vegetative types inhabited by goats were collected for use as reference specimens to identify plants and parts of plants concerned in the food habits evaluation.

3. Seven 100-ft. line transects were used as an indication of the plants present in four vegetative types. Animal use of plants on these transects was recorded.

4. A total of 149 days was spent in immediate goat habitat. A total of 795 goats was observed feeding throughout the day, with peaks suggested in morning and evening.

5. The order of importance of vegetative types as feeding areas was: grassy slide-rock slopes, ridge tops, alpine meadows, timber and cliffs.

6. Twenty-seven stomach samples, representing all seasons, were collected and analysed. The procedure of analysis is described.

7. The results of this study indicate that grasses, sedges and rushes were taken more commonly than any other class of plants during all seasons. Forbs were next in importance in summer and fall, but third in winter and spring. Coniferous trees were second in winter and spring, but unimportant in summer and fall. Shrubs, mosses, lichens, and ferns were minor items throughout the year.

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BLACK BEAR DAMAGE TO REDWOOD REPRODUCTION

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In recent years an unusual type of damage to a variety of species of second-growth trees has been reported in several of the western states (Levine, correspondence, Simpson Lookout, Sept., 1951) as well as Alaska and Canada (H. J. Lutz, Jour. Forestry, **49**(7): 522–523, 1951). This damage generally has been charged to the black bear (*Euarctos americanus*). Although, the woodrat (*Neotoma* sp.) and the gray squirrel (*Sciurus g. griseus*) have also received consideration (E. Fritz, Jour. Mamm. **13**(1): 76, 1932). For the most part, the damage is characterized by a stripping of the bark from the lower portion of the tree trunk with shallow, vertical grooving prominent on the exposed cambium.

This study was instigated when similarly stripped second-growth redwood (*Sequoia sempervirens*) became sufficiently noticeable in the vicinity of Little River, Humboldt County, California, to be of economic concern (Fig. 1). A preliminary survey of the damage was carried on by the Wildlife Department of Humboldt State College from September 1, 1951 to January, 1952. The California Redwood Association financed and administered the major portion of this research project, which was initiated in February and completed in August, 1952. The author is deeply indebted to Edward L. Hansen, field assistant, for enthusiastic aid on the project and to William Stickel, U. S. Fish and Wildlife Service for editorial assistance.

FIG. 1. Black bear damage to second-growth redwood in Humboldt County, California.

FIG. 2. Strips of bark and cambium removed by black bear from a redwood tree 10 to 20 years old.

Several objectives were established at the beginning of this project: (1) to determine the animal responsible for the major portion of the damage to the redwood reproduction; (2) to determine the severity of the damage; and, (3) to determine if the damage was increasing or decreasing.

The area surveyed consisted of approximately 45,000 acres, of which 30,000 were cutover lands and about 15,000 were burned in 1945 on Hammond Lumber Company land in the vicinity of Big Lagoon, Humboldt County. Redwood composed the major part of the stand in the survey area. Douglas fir (*Pseudotsuga menziesii*) and alder (*Alnus* sp.) were common. Manzanita (*Arctostaphylos* sp.), salal (*Gaultheria shallon*), blue blossom (*Ceanothus thyrsiflorus*), and coyote bush (*Baccharis pilularis*) were the dominant ground-cover plants. Stocking varied considerably over the entire area and the age of the second-growth redwood stand varied from about 7 to 47 years. The general terrain was dissected and ranged from approximately 200 feet to 2,500 feet above sea level.

Damage to redwood reproduction was of importance to the lumber companies for the following reasons: (1) fire hazard was increased by the dead and dying trees; (2) future commercial timber was lost or damaged; and (3) there seemed to be a possibility of the damage spreading throughout the redwood region.

Detailed observations of damaged trees revealed that the bark had been removed in strips (Fig. 2). On some trees the bark had been broken loose near the base and stripped upwards, often remaining attached at the top. On other trees the bark appeared to have been torn loose at some distance above the ground and then stripped down, with loose ends hanging in the branches or lying on the ground. Strips of removed bark were frequently found completely detached from the trunk and scattered about the base of the tree. These strips of peeled bark

ranged from small shreds to pieces about eight inches in width and 10 to 15 feet long. Unpeeled bark on damaged trees did not seem to be marked in any characteristic manner, but in general it appeared to be fluffier than bark found on undamaged trees. Whether this condition was an after effect or was present before the damage occurred was not determined. Limbs and branches were not observed to have been stripped on damaged trees. However, some of these limbs had loose bark at the time of examination; this condition was believed to have been caused by natural drying of the wood following damage.

An intensive survey was made on six sample study areas of 1,469 damaged trees. A total of 135 freshly damaged redwood trees (stripped during spring of 1952) were examined during May and June and bear hairs were collected and identified from 118 (87.4 per cent). During July an additional 99 freshly damaged trees were examined and bear hair was found on 80 per cent of them. On trees that had 0–25 per cent of their circumferal bark area damaged, the incidence of bear hair was 60 per cent. On trees with greater damage, occurrence of bear hair was correspondingly greater: 26–50 per cent area damaged, 92 per cent with bear hair; 51–75 per cent area damaged, 100 per cent with bear hair. Analysis of 24 bear scats collected in the survey area revealed redwood cambium scrapings in seven (29 per cent).

A comparison of diagonal scratch marks at points of entry in the bark checked satisfactorily with the spread and size of a bear's forefoot. In the vicinity of Squaw Peak a portion of a bear claw was collected from a tree that had about 90 per cent of its circumferal area freshly damaged. Prominent vertical engravings on the cambium of stripped trees (Fig. 3) corresponded in size and arrangement with the upper incisors of the black bear. On about 10 per cent of the trees, slightly different vertical engravings were found that had been made by the lower incisors.

Numerous broken limbs of various sizes were found on damaged trees, with the largest diameter being two inches. Six broken limbs measured in the course of the study varied from 1.5 to 1.75 inches in diameter at the point of breaking. In testing the strength of a limb 1.5 inches in diameter, it was found that it could support a weight of 160 pounds and not break, thus indicating that an animal of heavier weight had broken the limbs.

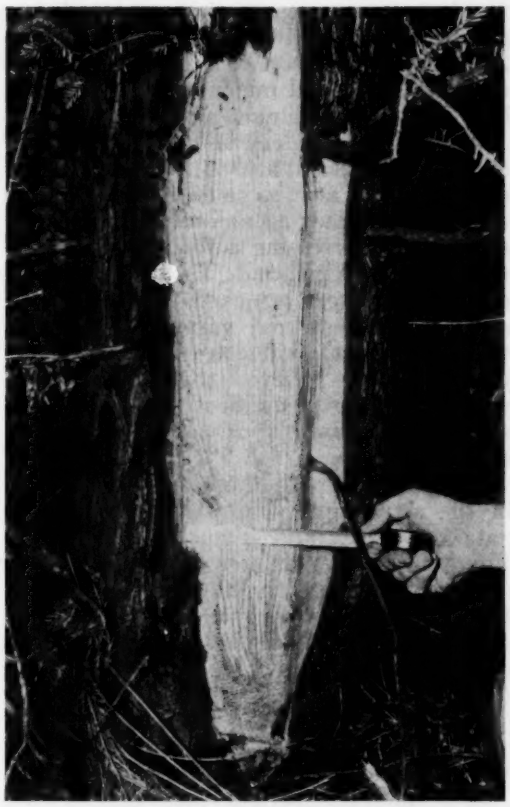

FIG. 3. Prominent vertical engravings in the cambium characterized black bear damage to second-growth redwood.

The high frequency of bear hair on freshly damaged trees along with other supportive data, seemed to indicate rather definitely that the black bear was the primary animal responsible for the extensive damage noted.

Trees damaged from one to three days before inspection were found to have only the typical vertical engravings of bears' incisors. Trees that had been damaged more than three days showed secondary multiple damage from teeth and claws of a wide variety of animals, mostly woodrats, mice, and chipmunks. Some field workers advanced the idea that the dusky-footed woodrat (*Neotoma fuscipes*) was responsible for the major portion of the injury to the young redwoods. This hypothesis was tested by placing four

woodrats in two cages that surrounded a group of redwood trees varying from 10 to 20 years old. The test was terminated when only incidental and minor gnawing of small branches was apparent after four weeks. Many insects, spiders, millipeds, and sow bugs were attracted also to the freshly damaged trees. As near as could be determined, secondarily attacking animals were not responsible for increasing the cambium damage more than five per cent. The large number of damaged trees attacked secondarily by such a multitude and variety of animals, with a resulting confusion of marks left on the trees, was believed to have been responsible for the past difficulty of field workers in determining the primary animal causing the damage.

The transect method of cruising was used in the six sample survey areas to obtain data on extent and intensity of damage. From an analysis of these data, the peak of damage was found to have been in 1950, following a rather steady increase since 1942. However, the bulk of the damage found in the survey areas had occurred after 1948 (Table 1).

TABLE 1.—PERCENTAGES OF DAMAGE FOR AREA BY YEAR AS DETERMINED FROM AN EXAMINATION OF SCARS ON 1,235 REDWOOD TREES

Survey Areas	Year of Damage									
	1942	43	44	45	46	47	48	49	50	51
Panther Creek	..	..	..	..	1	3	14	24	33	21
South Maple Creek	..	..	..	..	3	11	18	24	24	16
North Maple Creek	..	..	..	..	..	..	..	18	47	33
Squaw Peak	..	..	..	..	..	1	6	23	42	26
Devil's Creek	..	..	..	..	..	..	..	16	32	52
Little River	1	..	1	..	5	8	17	27	24	14

Damage to redwood reproduction, both old and fresh, tended to be heaviest in trees of the 10- to 20-year age group, with the majority of it in trees less than 30 years old. Indications were that the 5- to 10-year age class was subjected to increased depredation after 1950 (Table 2). In both old and freshly damaged trees, those most often peeled were in the 6- to 10-inch d.b.h. (diameter breast high) group (Table 3), but this varied widely in the six survey areas. While most stripping

TABLE 2.—DAMAGED TREES GROUPED BY AGE CLASSES AND EXPRESSED AS A PERCENTAGE OF THE TOTAL DAMAGED TREES EXAMINED

Survey Areas	Age Classes				
	5–10 yrs.	10–20 yrs.	20–30 yrs.	30–40 yrs.	40–50 yrs.
Panther Creek					
Old*	2.8	27.4	53.1	14.8	1.7
Fresh**	23.3	26.6	46.6	3.3	..
South Maple Creek					
Old	4.0	26.2	49.1	9.7	10.8
Fresh	47.4	31.6	21.0	..	..
North Maple Creek					
Old	56.0	39.4	4.5	..	..
Fresh	54.3	37.1	8.5	..	..
Squaw Peak					
Old	17.1	55.4	24.5	1.7	1.1
Fresh	25.8	44.8	27.5	1.7	..
Devils Creek					
Old	17.1	15.6	50.7	9.7	6.7
Fresh	20.0	20.0	47.5	12.5	..
Little River					
Old	..	4.5	13.7	9.1	72.5
Fresh	..	..	10.0	20.0	70.0

* Trees damaged prior to 1952.
** Trees damaged in 1952.

was less than 10 feet from the ground, it was not limited to this zone but extended from ground level, and exposed roots, up the trunk as much as 80 feet.

Bears apparently attacked the trees without any definite pattern of behavior with respect to amount of damage inflicted, for in an analysis of the extent of circumferal bark removed, it was found that about as many trees were in the 0–25 per cent damaged group as were in the 76–100 per cent group (Table 4). Degree of stocking seemed to have an influence on severity of damage, for slightly over 70 per cent of the injured trees were less than six feet from another tree. The data also indicated that "limby" trees, those with limbs sufficiently strong and regularly spaced to make them easy to climb by man, were more likely to be attacked than trees with clear boles. This indicated the possible use of silvicultural trimming as a means of alleviating the damage.

Approximately 20 per cent of the old damaged trees had been damaged in more than one year but only 6.5 per cent were injured more than twice. Of 234 freshly

TABLE 3.—PERCENTAGE OF DAMAGED TREES BY DIAMETER CLASS AS DETERMINED FROM AN EXAMINATION OF 1,469 TREES ON HAMMOND LUMBER COMPANY LAND

Survey Areas	Diameter Classes (d.b.h.)							
	4–6″	6–8″	8–10″	10–12″	12–14″	14–16″	16–18″	18+″
Panther Creek								
Old	1.7	1.1	10.2	17.1	20.0	33.1	14.8	1.7
Fresh	3.3	20.0	13.3	13.3	33.3	13.3	3.3	..
South Maple Creek								
Old	..	4.0	5.1	21.4	24.0	25.1	9.7	10.8
Fresh	5.3	42.1	15.8	15.8	5.3	15.8	..	..
North Maple Creek								
Old	17.7	38.2	27.4	12.0	4.5	..	..	..
Fresh	14.3	40.0	20.0	17.4	2.8	5.7	..	..
Squaw Peak								
Old	6.2	10.8	31.4	24.0	20.0	4.5	1.7	1.4
Fresh	8.6	17.2	32.8	12.1	8.6	19.0	1.7	..
Devils Creek								
Old	4.4	12.7	11.2	4.4	20.9	29.8	9.7	6.7
Fresh	10.0	10.0	12.5	7.5	27.5	20.0	12.5	..
Little River								
Old	..	..	..	4.5	8.0	5.7	9.1	72.5
Fresh	..	..	..	..	..	10.0	20.0	70.0

TABLE 4.—DATA FROM 1,469 SECOND-GROWTH REDWOOD TREES SHOWING THE RELATIVE SEVERITY OF CIRCUMFERAL BARK DAMAGE BY BLACK BEARS

Survey Areas	Percentage of Circumferal Bark Area Damaged			
	0–25	26–50	51–75	76–100
Panther Creek				
Old	51.43	19.43	11.42	17.72
Fresh	36.67	20.00	20.00	23.33
South Maple Creek				
Old	44.57	12.57	13.72	29.14
Fresh	42.10	10.53	15.79	31.58
North Maple Creek				
Old	36.57	16.57	8.00	38.86
Fresh	40.00	31.43	8.57	20.00
Squaw Peak				
Old	38.85	14.29	8.57	38.29
Fresh	27.60	15.50	32.80	24.10
Devils Creek				
Old	30.60	19.40	12.69	37.31
Fresh	47.50	27.50	10.00	15.00
Little River				
Old	22.86	26.28	19.43	31.43
Fresh	20.00	20.00	20.00	40.00

damaged trees, approximately 48 per cent had been attacked in previous years. Incidence of fresh peeling on previously damaged trees was regarded as severe in the North Maple Creek and Devil's Creek areas, where the frequency of redamaged trees was 65 per cent and 63 per cent respectively.

An average of 16 acres were intensively surveyed on each of the six sample areas. The number of damaged trees per acre was found to range from 8 to 15 with a mean of 11.6. This mean was close to a previous average (12.3 damaged trees per acre) calculated from data obtained on a general timber survey conducted in 1948 and 1949 by the Hammond Lumber Company. The rate of additional annual damage as determined from scar history was approximately six per cent. This may seem like a relatively unimportant annual increment, but its significance is clear when one realizes that a 90-year cutting cycle is currently used in managing this forest type.

As near as could be determined from field observations, the average number of trees that might be damaged by an individual bear in a 24-hour period was 20. In several areas it was apparent that as many as 40 trees had been injured during a 24-hour period. It is doubted that all of the damage occurred during the night, as was commonly thought, for on five instances bears were frightened from or observed feeding in stands of young redwoods during the day.

According to the Hammond timber survey, 80 per cent of the stand in the Big Lagoon timber management area was composed of conifers, with 57 per cent redwood and 21 per cent Douglas fir. Damage to young stands of Douglas fir apparently had not occurred with sufficient frequency to be noticed or to be of importance in northwestern California prior to the spring investigation of 1952. Correspondence (November 23, 1951) from Mr. Levine, of the South Olympic Tree Farm in Washington, mentioned severe bear depredations to Douglas fir in that region. The writer believes redwood to be the preferred species for attack, or the one most likely to be damaged if it is present, for the following reasons: (1) Douglas fir received heavy damage in other states but received only minor damage in the Humboldt area where there was an abundance of redwood; (2) a 5.2-acre redwood plantation, with some Port Orford cedar (*Chamaecyparis lawsoniana*), near Pysht, Washington, was damaged to the point that approximately 60 per cent of the trees were injured and about 40 per cent killed. On the Pysht Farm—in the same region but stocked with Douglas fir, hemlock (*Tsuga heterophylla*), spruce (*Picea sitchensis*), and cedar—approximately 40 per cent of the trees were injured with only 15 per cent killed (correspondence with C. E. Tulloch, Pysht Tree Farm, Washington on December 11, 1951). Data from the Humboldt County survey indicated that bears showed a preference for young redwood, for only 9 per cent of 234 freshly injured trees examined were Douglas fir. However, with increased and continued cutting of redwood timber, the composition of subsequent stands was expected to change to a higher percentage of Douglas fir; therefore, increased damage to Douglas fir may be anticipated.

The first date of fresh damage found in 1952 was May 7, with the last known date of injury being July 31. Supportive records from previous years, coupled with present data, indicated that the annual tree-damage period varied from 75 to 120 days in length and occurred during the months of April, May, June, July, and possibly August, depending upon seasonal climatic conditions.

Determination of whether damage was increasing or decreasing in certain areas was made from a density—time factor obtained by dividing the number of damaged trees found by the hours required to find the trees. From an analysis of old damage alone, the Little River drainage had sustained the heaviest damage and the Devil's Creek area the lightest (Table 5). On the other hand, analysis of freshly injured trees indicated that the Maple Creek drainage had the heaviest concentration of fresh damage. A clearer conception of the current situation was obtained from a comparison of the number of freshly damaged trees on the study areas with the number of trees damaged during any previous year on the same areas (Fig. 4). Apparently bear damage decreased slightly after the peak of 1950, possibly because of localized trapping efforts. There also seemed to be a shift in location of bear depredations, which might have been stimu-

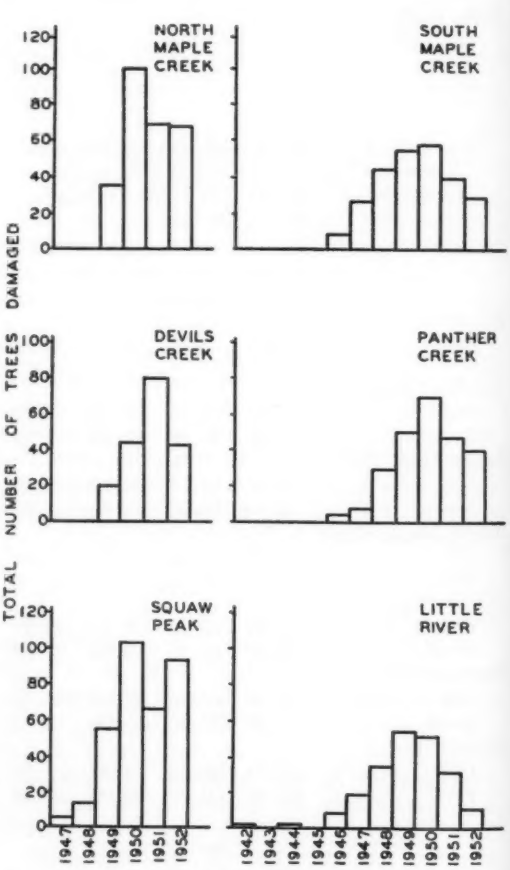

FIG. 4. Frequency of bear damaged redwood trees in relation to years on six sample survey areas, Humboldt County, California.

TABLE 5.—A COMPARISON OF THE DAMAGE INTENSITY ON SIX SAMPLE SURVEY AREAS IN HUMBOLDT COUNTY, CALIFORNIA

Survey Areas	Acres Surveyed	Number Trees Damaged	Trees Damaged Per Acre[1]	Density Damage Factor	
				Old Damage	Fresh Damage
Panther Creek	14	210	15	12.00	5.62
South Maple Creek	21	168	8	14.80	21.30
North Maple Creek	18	180	10	10.40	16.07
Squaw Creek	14	182	13	11.29	11.10
Devils Creek	14	182	13	9.51	5.87
Little River	14	182	13	22.34	3.18

[1] Normal stocking for second-growth redwood in this region ranges from 70 to 110 trees per acre.

lated by the trapping, from the Little River Basin to the Maple Creek drainage and the Squaw Peak area.

Further analysis of the problem is now hampered by our lack of understanding of factors that govern the attacks.

SUMMARY

The black bear was found to be responsible for most of the bark and cambium damage to redwood reproduction in Humboldt County, California.

There was a steady increase in extent and intensity of bear depredations on redwood to the peak year of 1950. In 1951 and 1952 there was a slight decrease.

Second-growth timber 10-30 years old was injured most, but there were indications that the 5- to 10-year age class was being damaged with increased intensity.

The annual tree-damage period occurred during spring and summer months and varied from 75 to 120 days.

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EDITOR'S NOTE

From the last week in March to the first week in September, Dr. Gustav A. Swanson served as "Acting Editor" of the JOURNAL OF WILDLIFE MANAGEMENT. The July issue was published entirely under his editorship, and he did most of the work on this issue.

May we express sincere appreciation both personally and on behalf of The Wildlife Society to "Gus" for so capably looking after the Journal.

Also, we wish to take this opportunity of thanking Dr. Carlton M. Herman for his assistance as Associate Editor during the past two years, and of welcoming Dr. Edward L. Kozicky and Mr. Robert W. Darrow as newly appointed Associate Editors.

—OLIVER H. HEWITT

RACES OF THE STRIPED BASS, *Roccus saxatilis* (WALBAUM), IN SOUTHEASTERN UNITED STATES

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A knowledge of the origin of the stock or stocks exploited in a fisheries is basic to sound management. A study to determine the racial structure of Atlantic Coast striped bass is under way and recent investigations of southeastern stocks have produced tentative concepts. The results should be considered preliminary because specimens from too few year classes are available for study. As used here the term "race" implies a lower level of differentiation than that of a subspecies.

The major published findings concerning racial problems to date are as follows: Merriam (1937 and 1941) and Vladykov and Wallace (1938) showed that some Chesapeake Bay striped bass, two years and older, undertake a non-spawning coastal migration northward in the spring. In the fall they return to Chesapeake Bay by approximately the same route although some migrants may enter and winter over in northern coastal rivers. Vladykov and Wallace (1952) indicated that different sub-races may make up the Chesapeake Bay race although adequate substantiating data are not presented. Raney and de Sylva (1953) showed that fin-ray counts in young striped bass were lower in samples from the Hudson River than those from Chesapeake Bay. The degree of differentiation was approximately 80 per cent, based on a character index combining dorsal, anal, and total pectoral soft-ray counts. They also suggested that the Hudson River may contain an upstream and a downstream population. Raney, Woolcott, and Mehring (1954) concluded that (a) the Hudson River race migrates to the western quarter of Long Island Sound and the region near the mouth of the Hudson River including the northeastern New Jersey shore and the south shore of Long Island east to Jones Beach; (b) fin-ray counts of young of the 1953 year class confirmed the findings based on other year classes concerning the racial separation of Chesapeake and Hudson River striped bass; (c) in fin-ray counts, samples from Rhode Island and northward are close to the Chesapeake race; (d) although shifts in the fin-ray counts occur from year to year the change is slight compared to the degree of differentiation between races and usually has little effect on the percentage of separation; and, (e) Albemarle Sound samples differ from South Carolina series in lateral-line scale counts.

Material

Samples from Albemarle Sound were mostly young of several year classes but include some juvenile and adult specimens. Those from the Santee-Cooper River, South Carolina, were mostly young (Lake Marion) and yearlings of the 1954 and 1953 year classes which were made available by George D. Scruggs, Jr. and Jefferson C. Fuller, Jr., of the South Carolina Wildlife Resources Department. Prior to this, our South Carolina sample consisted of only ten young and small adults which were loaned by E. Milby Burton and Albert Schwartz of the Charleston Museum. An adequate sample of adult striped bass from the St. Johns River system in eastern Florida was counted during September 1954 by William M. McLane of the Florida Game and Freshwater Fish Commission and the authors. Only four specimens of striped bass have been examined from the Gulf of Mexico drainages of Florida and Mississippi. It is hoped that additional specimens will be

[1] Supported by the U. S. Fish and Wildlife Service as part of the Atlantic States Cooperative Striped Bass Program sponsored by the Atlantic States Marine Fisheries Commission. A modified version of this paper was presented as part of a panel on striped bass at the Eighth Annual Conference of the Southeastern Association of Game and Fish Commissioners, New Orleans, November 1, 1954.

[2] Recipient of a Sport Fishing Institute Fellowship, 1953–54.

made available by Gulf Coast fishery biologists. The localities in South Carolina referred to below are shown in Figure 1.

CHARACTERS STUDIED

Fin-ray and lateral-line scale counts of young have been emphasized to date. Body proportions and scale structure may show differences from place to place but there are too few large specimens in our collections to prove this.

RESULTS

Lateral-line scale counts are shown in Table 1 and illustrated for southern samples in Figure 2. Northern stocks may differ from each other on a low level. Frequency distributions approximate the normal except for the Hudson and Cooper rivers where two types seem to be present. The Albemarle Sound sample differs on a relatively high level from the South Carolina composite sample; the average separation is 76 per cent when a line is drawn between 60 and 61 scales (see Ginsburg, 1938). The St. Johns River, Florida, sample averages lower than the composite South Carolina sample; 85 per cent average separation is obtained when a line is drawn between 56 and 57 scales. The St. Johns River sample is separated 93 per cent on the average from the Albemarle Sound sample.

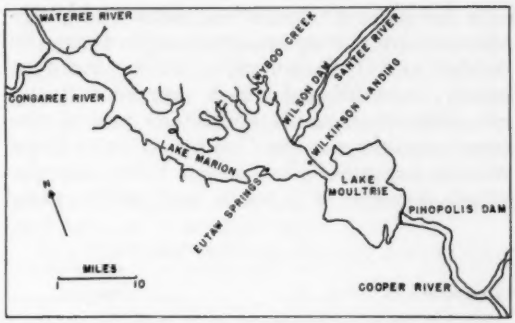

FIG. 1. Outline map showing collecting stations in the Santee-Cooper reservoir system, South Carolina.

An examination of the South Carolina samples indicates that two stocks may be present. One is represented by the four samples from Lake Marion and a small sample from Lake Moultrie. Here the lateral-line counts are relatively high, usually 58 to 60. Samples within Lake Marion, which consisted only of young of the 1954 year class, differ somewhat from place to place as did samples taken at the same locality (Wilkinson Landing) at different times (Fig. 2). It is to be noted that these differences are not significant.

TABLE 1.—FREQUENCY DISTRIBUTION OF LATERAL-LINE SCALES IN STRIPED BASS. THE LAST COLUMN (%) INDICATES THE PERCENTAGE OF SPECIMENS WITH 60 OR FEWER SCALES

Locality	Lateral-Line Scales																	No.	Mean	%
	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67				
St. Lawrence R.	..	..	..	..	..	4	7	11	14	16	14	14	17	2	..	..		99	61.3	36
New Brunswick	..	..	1	1	4	3	12	16	29	20	25	14	7	6	6	..		144	60.9	46
Rhode Island	..	..	..	..	1	4	2	5	9	10	12	13	4	7	1	1		69	61.6	30
Hudson River	..	..	1	2	5	6	8	10	6	13	8	2	3	1	..	..		65	59.6	58
Delaware River	..	..	..	..	..	..	2	4	9	19	17	10	12	5	3	2		83	62.2	18
Chesapeake Bay	..	1	..	2	9	14	14	26	31	27	33	13	8	2	..	..		180	60.1	54
N.C., Albemarle Sound	..	..	..	..	..	..	2	4	6	11	8	3	3	4	2	..		43	61.7	28
S.C., Lake Marion	1	..	4	9	14	24	25	41	39	33	20	9	4	..	..	..		223	59.2	70
Wyboo Cr.	..	..	1	4	4	9	12	16	23	11	11	7	3	..	..	..		101	59.6	68
Eutaw Sp.	1	..	..	1	3	2	2	4	3	3	1	2	1	..	..	..		23	59.0	70
Wilkinson Ld.																				
Sept. 10	..	1	2	4	7	9	9	16	10	5	5	..	..	..	..	..		68	58.3	85
Sept. 27	..	..	1	..	..	4	2	5	3	4	3	..	..	..	..	..		22	59.2	68
Lake Moultrie	..	..	..	2	..	1	1	1	2	1	1	1	..	..	..	..		10	59.9	70
Cooper River	1	5	7	5	9	5	11	11	7	..	..	..	..	..	..	..		61	56.8	100
Ashley and Edisto R.	1	1	..	4	..	..	1	..	1	..	..	..	..	..	..	..		8	55.4	100
Fla., St. Johns R.	4	4	8	4	3	1	1	..	..	..	..	..	..	..	..	..		25	54.2	100

Counts on St. Lawrence samples furnished by V. D. Vladykov.

A down-river population seems to be represented by the composite sample from the Ashley and Edisto rivers, which, unfortunately, is small and which represents juvenile and small adult specimens not of the same year class as the Cooper River or Lake Marion samples. The Cooper River sample, which consists of juvenile and adult specimens, is intermediate between the Lake Marion population and the South Carolina Coastal Plain population. It also shows a bimodal distribution (Table 1). These specimens were taken below Pinopolis Dam and seem to represent both spawning migrants from downstream and Lake Marion bass which perhaps came downstream through the navigation locks. The lowland or Coastal Plain population of South Carolina appears to occupy an intermediate position in lateral-line scales between the Cooper River and St. Johns River, Florida populations.

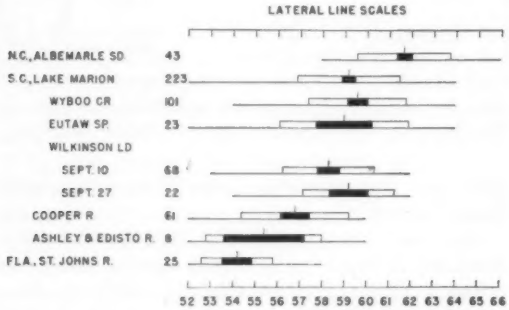
LATERAL LINE SCALES
N.C., ALBEMARLE SD. 43
S.C., LAKE MARION 223
WYBOO CR 101
EUTAW SP. 23
WILKINSON LD.
SEPT. 10 68
SEPT. 27 22
COOPER R. 61
ASHLEY & EDISTO R. 8
FLA., ST. JOHNS R. 25
52 53 54 55 56 57 58 59 60 61 62 63 64 65 66

FIG. 2. Lateral-line scale counts of striped bass. For each locality the range of variation is shown by a heavy horizontal line, the mean by a vertical line. The blackened part of each bar comprises two standard errors of the mean on either side of the mean. One-half of each black bar plus the white bar at either end, outline one standard deviation on either side of the mean. Considerable reliance can be placed on the significance of the difference between samples if the corresponding black bars are separated or only slightly overlap. Method of representation adapted from Hubbs and Hubbs (1953: 51).

A cline is observable in the distributions shown in Figure 2; they vary from low counts in the south to high counts in the Albemarle Sound samples. No cline is represented by our samples from north of Albemarle Sound.

FIN-RAY COUNTS

Anal-ray counts are given in Table 2. There seems to be little difference in anal-ray counts in samples from Albemarle Sound and southward except for the inadequate sample from west Florida and Mississippi which have 10 rather than 11 anal rays. The numbers of anal rays seem rather stable except perhaps for the New Brunswick, Canada, sample. The upper Hudson River race also has a low average.

Dorsal-ray counts are given in Table 3.

TABLE 2.—NUMBER OF ANAL SOFT RAYS IN STRIPED BASS. THE LAST COLUMN (%) GIVES THE PERCENTAGE OF SPECIMENS WITH 10 OR FEWER RAYS

Locality	Anal Rays 7	8	9	10	11	12	13	No.	Mean	%
St. Lawrence River	..	..	..	21	79	..	..	100	10.8	21
New Brunswick	1	1	13	61	66	1	1	144	10.4	53
Nova Scotia	..	..	..	..	39	..	..	39	11.0	0
Hudson River (upper)	..	..	8	107	142	3	..	260	10.6	44
Delaware Bay	..	..	2	46	190	2	..	240	10.9	20
Chesapeake Bay	.	..	..	124	825	3	..	952	10.9	13
N.C., Albemarle Sound	..	..	..	4	56	..	..	60	10.8	10
S.C., Lake Marion	..	..	.	6	218	1	..	225	11.0	3
Wyboo Cr.	..	..	..	3	98	..	..	101	11.0	3
Eutaw Sp.	..	..	..	..	23	..	..	23	11.0	0
Wilkinson Ld.										
Sept. 10	..	..	..	3	64	1	..	68	11.0	4
Sept. 27	..	..	..	..	25	..	..	25	11.0	0
Lake Moultrie	..	..	..	..	8	..	..	8	11.0	0
Cooper River	..	..	..	7	55	..	..	62	10.9	11
Ashley and Edisto R.	..	..	..	1	7	..	..	8	10.9	13
Florida, St. Johns R.	..	..	..	1	22	2	..	25	11.0	0
West Fla. and Miss.	..	..	1	3	..	..	..	4	9.8	100

The count is modally 12 in the geographic area between Albemarle Sound and Mississippi. A slight difference is found in comparing those from Lake Marion with those from Cooper River below Pinopolis Dam. The Hudson River race is unique; samples have 11 rather than 12 as the modal number.

The total pectoral-ray counts are shown in Table 4 and in Figure 3. There is an indication of population differentiation within the Santee-Cooper River system in this character; the upstream population has the higher count. The St. Johns River, Florida, population has the highest count found along the Atlantic Coast and approaches the values for New Brunswick and Nova Scotia samples. The west Florida-Mississippi sample yielded a low count, the lowest found in any sample of striped bass.

For the most part the fin-ray counts vary

TABLE 3.—NUMBER OF DORSAL SOFT RAYS IN STRIPED BASS. THE LAST COLUMN (%) GIVES THE PERCENTAGE OF SPECIMENS WITH 11 OR FEWER RAYS

Locality	Dorsal Rays 9	10	11	12	13	14	No.	Mean	%
St. Lawrence River	..	1	30	69	..	..	100	11.7	31
New Brunswick	..	10	17	124	1	..	144	11.9	13
Nova Scotia	..	..	1	38	..	..	39	12.0	3
Hudson R. (upper)	2	24	183	38	1	1	249	11.1	84
Delaware Bay	..	6	99	128	7	..	240	11.6	44
Chesapeake Bay	..	7	248	687	8	1	951	11.8	27
N.C., Albemarle Sound	..	..	9	51	..	..	60	11.8	15
S.C., Lake Marion	..	..	70	146	1	..	217	11.7	32
Wyboo Cr.	..	..	28	73	..	..	101	11.7	28
Eutaw Sp.	..	..	5	18	..	..	23	11.8	22
Wilkinson Ld.									
Sept. 10	..	.	27	40	1	..	68	11.6	41
Sept. 27	..	..	10	15	..	..	25	11.6	40
Lake Moultrie	..		4	12	..	..	16	11.8	25
Cooper River	..	5	16	40	1	..	62	11.6	34
Ashley and Edisto R.	..	..	..	8	..	..	8	12.0	0
Florida, St. Johns R.	..	..	2	23	..	..	25	11.9	1
West Fla. and Miss.	..	..	..	4	..	..	4	12.0	0

TABLE 4.—NUMBER OF PECTORAL RAYS (BOTH SIDES) IN STRIPED BASS. THE LAST COLUMN (%) GIVES THE PERCENTAGE OF SPECIMENS WITH 32 OR FEWER RAYS

Locality	Pectoral Rays 27	28	29	30	31	32	33	34	35	36	37	38	No.	Mean	%
New Brunswick	..	..	..	..	..	13	14	112	5	..	..	..	144	33.8	9
Nova Scotia	..	..	..	..	..	3	7	25	4	..	..	..	39	33.8	8
Hudson R. (upper)	..	2	7	14	29	134	33	36	1	..	..	..	256	32.1	73
Delaware Bay	..	..	4	..	18	55	53	73	29	2	..	..	234	33.1	33
Chesapeake Bay	1	4	6	23	27	182	168	406	75	37	6	1	936	33.4	26
N.C., Albemarle Sound	..	..	..	..	..	26	10	24	..	..	..	..	60	32.9	43
S.C., Lake Marion	..	..	1	..	8	35	43	120	9	1	..	..	217	33.4	20
Wyboo Cr.	..	..	..	..	4	15	16	60	6	..	..	..	101	33.5	19
Eutaw Sp.	..	..	..	..	1	1	4	17	..	..	..	..	23	33.6	8
Wilkinson Ld.															
Sept. 10	..	..	1	..	2	13	18	32	1	1	..	..	68	33.2	23
Sept. 27	..	..	..	..	1	6	5	11	2	..	..	..	25	33.3	28
Lake Moultrie	..		..	..	..	2	8	..	..	..	..	..	10	32.8	20
Cooper R.	..	..	1	1	2	25	17	14	1	1	..	..	62	32.7	47
Ashley and Edisto R.	..	..	..	..	1	4	..	3	..	..	..	..	8	32.6	63
Fla., St. Johns R.	..	..	..	..	..	1	4	16	1	2	..	..	24	34.0	0
West Fla. and Miss.	..	..	..	..	2	2	..	..	..	..	..	..	4	31.8	100

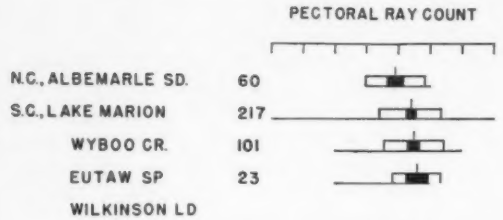

FIG. 3. Total pectoral-ray counts of striped bass.

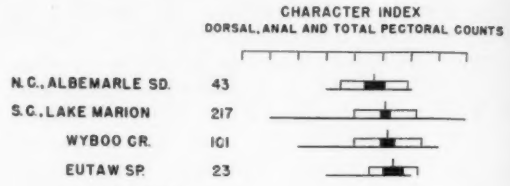
CHARACTER INDEX
DORSAL, ANAL AND TOTAL PECTORAL COUNTS
N.C., ALBEMARLE SD. 43
S.C., LAKE MARION 217
WYBOO CR. 101
EUTAW SP. 23
WILKINSON LD.
SEPT. 10 68
SEPT. 27 25
COOPER R. 62
ASHLEY & EDISTO R. 8
FLA., ST. JOHNS R. 24
51 52 53 54 55 56 57 58 59

FIG. 4. Character indices for samples of striped bass. The index was obtained by adding dorsal, anal, and total pectoral soft rays.

in the same direction and an index formed by adding anal, dorsal, and pectoral soft rays gives a total picture of the trend (Table 5, Figure 4). The Albemarle Sound and the composite South Carolina population do not differ significantly. The St. Johns River, Florida population differs from the west Florida-Mississippi population; each apparently represents an extreme trend. Both differ significantly from the South Carolina and Albemarle samples. Within the Santee-Cooper River system, South Carolina, there seems to be an indication of two different populations. The upstream population has the higher index.

DISCUSSION

In view of the differentiation in lateral-line scales found in the North Carolina, South Carolina, and east Florida stocks it seems pertinent to consider the possible causes of these differences. The authors favor

TABLE 5.—FREQUENCY DISTRIBUTION OF THE CHARACTER INDEX (SUM OF DORSAL, ANAL, AND PECTORAL SOFT RAYS) IN STRIPED BASS. THE LAST COLUMN (%) INDICATES THE PERCENTAGE OF SPECIMENS WITH AN INDEX OF 55 OR LESS

Locality	Character Index																	
	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	No.	Mean	%
New Brunswick	..	..	..	..	..	2	4	11	22	50	48	7	..	..	..	144	56.0	23
Nova Scotia	..	..	..	..	..	..	..	..	3	8	24	4	..	..	..	39	56.7	8
Rhode Island	..	..	..	..	1	..	..	5	12	16	26	4	2	1	..	67	56.3	27
Hudson River	..	..	1	5	13	27	49	74	59	23	22	1	..	..	..	274	54.0	83
Delaware River	1	..	..	..	1	1	4	15	15	18	18	9	1	..	..	83	55.6	45
Chesapeake Bay	..	..	..	..	1	5	9	25	80	127	219	55	27	2	1	551	56.4	22
N.C., Albemarle Sound	..	..	..	..	..	..	2	4	12	11	14	..	..	..	..	43	55.7	42
S.C., Lake Marion	..	..	..	..	..	1	6	13	40	68	81	7	1	..	..	217	56.1	28
Wyboo Cr.	..	..	..	..	..	..	4	6	13	27	46	5	..	..	..	101	56.2	23
Eutaw Sp.	..	..	..	..	..	..	..	1	3	5	14	..	..	..	..	23	56.4	17
Wilkinson Ld.																		
Sept. 10	..	..	..	..	..	1	2	3	19	24	16	2	1	..	..	68	55.8	37
Sept. 27	..	..	..	..	..	..	..	3	5	12	5	..	..	..	..	25	55.8	32
Lake Moultrie	..	..	..	..	..	..	..	..	1	3	4	..	..	..	..	8	56.4	13
Cooper R.	..	..	..	..	1	1	5	11	18	14	10	2	..	..	..	62	55.2	58
Ashley and Edisto R.	..	..	..	..	..	..	..	1	4	1	2	..	..	..	..	8	55.5	62
Florida, St. Johns R.	..	..	..	..	..	..	..	..	1	6	12	4	1	..	..	24	56.9	4
West Fla. and Miss.	..	..	..	..	..	..	1	1	2	..	..	..	..	..	..	4	54.3	100

the hypothesis that scale counts and fin-ray characters are genetically fixed in striped bass but may fluctuate within a narrow range in response to environmental changes, such as temperature, at the time these characters are determined in the embryo. Experimental evidence to date (see Tåning, 1952, for references) with other fishes usually indicates an increased number of parts with lower water temperatures. The data on lateral-line scale counts (Table 1) show a gradual or clinal increase from St. Johns River, Florida northward to Albemarle Sound. However, no such cline is noted in comparing samples from Chesapeake Bay to the St. Lawrence River, an area which certainly experiences varied temperature conditions. An increase occurs in an upstream direction within the Santee-Cooper River system. A slight decrease is noted upstream in the Hudson River.

Under experimental conditions, fin-ray counts normally shift in the same direction as do lateral-line scales; a higher number at lower water temperatures. Where differences do occur in fin-ray counts in the region from the St. Johns River, Florida, to Albemarle Sound, a reverse trend, a slight decrease toward the north, exists. Within the Santee-Cooper River system there is a slight increase in an upstream direction. Perhaps the water temperatures at spawning time are lower downstream below Pinopolis Dam. Upstream in the Hudson River the number of dorsal rays definitely decreases.

For the most part critical temperature data at spawning time are lacking so that we do not know that shifts in the fin-ray and scale counts in the striped bass are correlated with temperature. Furthermore, in nature spawning does not usually occur in striped bass until a threshold temperature of about 58°F. is reached. The incubation period is short; 48 hours at 64.2°F. (Pearson, 1938: 831). The "supersensitive" period when the embryo is especially sensitive is not known but is likely to be of short duration, seemingly a matter of hours. It seems probable that widely separated populations of striped bass along the Atlantic Coast may undergo early development at about the same water temperature. Pronounced changes in temperature due to sudden storms might cause shifts which could result in an unusual distribution of counts for part of a year class. Such differences would tend to balance out if samples including several year classes were used. These problems may be clarified by researches to be carried on over the next three years.

Whether the cause of the differences which have been found to exist is primarily genetic, or is a result of environmental modification of the phenotype, makes relatively little difference as long as the variations in a given area are approximately the same from year to year. To date, an insufficient number of year classes of striped bass have been studied from the southeastern United States, but in the Hudson River where studies have been made of several year classes since 1949 relatively small differences in counts have been noted from year to year.

The meristic data presented here, which indicate an upstream versus a downstream population in the Santee-Cooper River system, South Carolina, are strengthened by the findings of Scruggs and Fuller (1955) regarding migration within the river system. It is assumed that the Lake Marion stock was derived from an upriver stock which had already been differentiated much as has the upstream Hudson River race. When the rivers were dammed, the upstream form apparently found a suitable habitat and now represents a fishery of great potential value.

Samples of striped bass from many coastal areas where populations are known to occur are still lacking, and a future study of material from several Georgia rivers, as well as other waters in North and South Carolina, will further clarify the picture of racial structure of the stocks. Counts of the relatively few and inadequate samples from west Florida and Mississippi give indications of significant differences. There is little chance that there has been gene exchange between these and Atlantic populations since the emergence of the Florida peninsula from the seas.

SUMMARY

It is tentatively concluded that the South Carolina stock of striped bass is an endemic race which in turn is differentiated into an upstream form which may not go to the sea and a downstream form which at least goes downstream to brackish water. Certainly there is little interchange between South Carolina stock and that of Albemarle Sound, North Carolina, or the St. Johns River,

Florida. The latter is a good race but its relationships with populations immediately to the north in Georgia rivers are unknown.

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SOME LIMNOLOGICAL CONSIDERATIONS IN THE PRODUCTIVITY OF OKLAHOMA FARM PONDS[1]

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INTRODUCTION

As the human population continues to increase, additional sources of food must be utilized. It seems likely that the nations will turn to the water for a larger proportion of their food needs. Water areas comprise about 80 per cent of the earth's surface and are being utilized only to a modest degree in comparison to their potential production. The opportunity for expansion of food supplies from water must depend on limnologically sound information.

The southwestern states have a responsibility to aid in the development of an effective program of water conservation in its broadest sense. Water is one of the most critical materials in the area. Although over 100,000 small impoundments (average 1 acre) have been built in Oklahoma and although many larger impoundments (as large as 90,000 acres) exist, there has been no concerted effort to determine what constitutes good management of the water for all the people concerned.

Ponds are more accessible and easier to study than large impoundments, but much remains to be done before adequate guidance can be given to the pond owner with respect to the proper utilization of his pond. Ponds serve in many ways. Some of their uses include stock water, irrigation, household water supply, small-manufacturing-plant water supply, recreation centers for swimming, boating, and fishing, flood and erosion control, commercial minnow or food-fish production, and attraction of wildlife for esthetic values or hunting.

[1] Contribution Number 237 from the department of zoology and the Research Foundation, Oklahoma Agricultural and Mechanical College, Stillwater, Oklahoma.

Data used in this paper were collected from 59 ponds in Payne, Muskogee, and Oklahoma counties of Oklahoma during the period from 1949 to 1954. The number of trips to each pond ranged between one and fifty, and 4,306 individual records of the general limnological conditions were made. A summary of these data is presented in the belief that it will aid in the evaluation of the so-called "normal" pond. Observations were recorded during all seasons of the year in connection with various objectives, and represent as composite a picture of the true conditions as convenience of location and time allotted to the study would allow. An attempt was made to analyze the effect of each of the ecological "factors" studied as they apply to the localized conditions.

METHODS

The limnological techniques applied during this study are those recommended by Welch (1948). A modified Kemmerer sampler was used to collect water samples to be analyzed. Temperature records were secured with a Whitney model direct-reading thermometer of the electrical resistance type. A Hellige pH outfit with plastic disks served for hydrogen-ion determinations. Dissolved oxygen was determined by the Rideal-Stewart modification of the Winkler method. A conductivity bridge made by the Industrial Instrument Company was used to check the conductivity of the water.

LIMNOLOGICAL CONDITIONS

TEMPERATURE — Data on temperatures were collected from most of the ponds examined. In nearly all cases the temperature readings were taken in the afternoon and would represent a maximum or near maximum reading for the day. During one observation period the daily increase in surface water temperature from the time of daylight until about 4:00 P.M. was 9°F. This occurred on May 6 and at a time when the water at the lower levels was relatively cool.

The maximum temperature, that was recorded in a pond during the study was 96.5°F. on July 27, 1953. At that time the bottom temperature in the same pond (about 5 feet) was only 81°F. and the average temperature was 88°F. The minimum temperature recorded during the study was 32.4°F., registered by breaking surface ice of a pond 5-foot deep on December 7, 1950. In this pond the temperature of water just above the bottom was 40.8°F. At the same time the over-all average temperature was 36°F.

The temperature readings from all of the ponds were added together according to the month and the depth and an arithmetical average of temperature for each depth during each month was computed. The "average" temperatures are recorded in Table 1. There was a temperature change with depth during all months of the year. The ice cover was of insufficient duration to lower the average surface temperature as much as might be expected during January and in December. The most striking thing was that reverse stratification occurred even at the higher winter temperatures. Reverse stratification was not restricted to periods of ice cover but was present on several occasions even in the absence of an ice cover.

Reverse stratification is probably explainable on the basis of low wind velocity and higher viscosity of the cold water along with the proximity to disappearance of the ice cover. Birge (1910) stated that the influence of the wind varies with the square of its velocity and is affected greatly by the temperature and resultant viscosity. Cooling of the water from convexion currents is most effective in conjunction with disturbance of the water.

Although the water temperature was never constant from the surface to the bottom of a pond, the semi-permanent layering associated with the presence of a thermocline did not become evident from either individual ponds or the average (as given in Table 1) until April. The effect of a thermocline was most noticeable in June, and although insufficient data are listed for proof, the thermocline would seem to disappear during August.

The monthly average surface temperatures varied from 40.3°F. in the winter to 88.1°F. in the summer. Welch (1938) recorded a minimum surface temperature of 36.6°F. in April under ice and 78.8°F. as a maximum July reading in a Michigan bog pond. In Ohio approximately 32° to 82.4° was the monthly surface temperature range given by Dexter *et al.* (1942). Farther south, in Kansas, Ratzlaff (1952) recorded 39° to 81° for monthly average surface temperature.

It is perhaps also noteworthy that the difference in temperature between the sur-

TABLE 1.—THE NUMBERS OF TEMPERATURE READINGS TAKEN DURING EACH MONTH ARE GIVEN WITH AN ARITHMETICAL AVERAGE IN DEGREES, FAHRENHEIT, FOR EACH FOOT IN DEPTH OF THE PONDS

Depth in Feet	Jan.		Feb.		Mar.		April		May		June	
	No.	Temp.	No.	Temp.	No.	Temp.	No.	Temp.	No.	Temp.	No.	Temp.
0	36	40.3	18	49.6	23	53.9	24	63.3	11	71.5	25	84.4
1	29	40.5	10	50.5	23	53.5	22	62.6	11	71.4	19	83.2
2	29	40.6	10	48.9	23	52.1	22	59.5	11	71.5	19	81.0
3	29	40.6	10	48.2	23	50.8	22	58.5	11	70.9	23	79.3
4	29	40.8	10	48.0	23	50.2	22	56.9	11	70.7	19	76.9
5	22	40.5	12	46.5	19	49.8	19	55.9	11	69.9	16	75.7
6	10	40.5	8	46.4	18	48.8	15	54.6	11	69.6	19	74.2
7	5	41.2	5	45.8	8	48.5	5	56.1	10	70.0	13	72.3
8	5	41.2	5	45.8	6	49.1	4	57.7	10	66.0	12	70.2
9	5	41.4	4	45.6	5	49.4	4	57.3	10	63.2	12	68.4
10	4	41.5	4	45.5	5	48.7	4	57.2	9	60.6	16	66.2
11	3	41.4	3	45.4	2	47.1	4	56.4	7	58.5	11	65.5
12	2	42.3	3	44.8	2	46.6	4	54.0	8	57.4	11	64.6
13	2	42.3	3	44.8	2	46.3	3	52.4	7	54.9	10	63.7
14	1	42.8	3	44.5	2	46.2	1	50.0	8	52.9	9	62.5
15	1	42.8	3	44.5	1	46.5	1	50.0	7	52.0	8	61.3
16	1	42.8	2	45.7	1	46.5	1	50.0	4	51.7	5	59.2
17	1	42.8	1	47.0	..	....	..	....	1	53.0	3	58.6
18	1	42.8	..	....	..	....	..	....	..	....	2	57.7
19	..	....	..	....	..	....	..	....	..	....	2	56.7
20	..	....	..	....	..	....	..	....	..	....	2	55.9
21	..	....	..	....	..	....	..	....	..	....	2	55.4

TABLE 1.—*Continued*

Depth in Feet	July		Aug.		Sept.		Oct.		Nov.		Dec.	
	No.	Temp.	No.	Temp.	No.	Temp.	No.	Temp.	No.	Temp.	No.	Temp.
0	65	88.1	59	83.1	25	73.2	59	66.9	70	51.6	44	41.5
1	38	86.9	4	83.3	7	80.4	4	66.0	21	46.9	31	40.1
2	38	84.5	4	82.7	7	78.3	4	65.7	19	46.2	29	40.3
3	49	81.9	4	81.8	7	77.7	5	64.8	19	46.0	29	40.1
4	38	81.3	4	81.3	7	76.3	4	64.4	18	45.9	28	40.3
5	34	80.0	4	80.8	7	75.2	4	64.0	16	45.7	25	40.6
6	34	77.7	4	80.4	6	73.9	4	63.5	13	45.1	20	40.8
7	25	75.6	3	80.0	5	74.3	4	63.3	8	45.0	13	40.8
8	25	71.8	2	80.5	3	74.7	2	62.4	7	44.6	9	40.6
9	27	68.2	2	80.0	3	73.8	2	62.2	7	45.1	8	41.0
10	29	66.2	2	79.5	3	72.3	3	62.8	5	44.4	7	41.2
11	22	64.5	2	79.0	3	70.0	2	61.9	4	43.2	7	41.4
12	24	63.4	1	79.0	2	67.8	1	64.4	4	43.0	6	41.7
13	23	62.1	1	79.0	2	66.2	1	63.5	5	45.0	5	41.9
14	11	64.0	..	....	..	....	1	63.1	1	43.7	3	42.6
15	16	62.6	..	....	..	....	..	....	1	43.7	2	42.8
16	6	62.3	..	....	..	....	..	....	..	....	2	42.8
17	1	63.0	..	....	..	....	..	....	..	....	2	43.0
18	1	61.5	..	....	..	....	..	....	..	....	2	43.0
19	1	60.0	..	....	..	....	..	....	..	....	2	43.0
20	..	....	..	....	..	....	..	....	..	....	2	43.2
21	..	....	..	....	..	....	..	....	..	....	1	44.2

face and the bottom averages 2.5°F. for a minimum in January and averages 29°F. for a maximum in June. Also, some attention should be directed to the increase in average temperatures at lower depths as the season progresses.

Several authors have studied the importance of temperature in evaluating an

aquatic habitat for productivity. McCay (1925) states that a fish doubles its oxygen requirements with each eighteen-degree (Fahrenheit) increase in temperature. Fry and Hart (1948a; 1948b) say that the cruising speed of a goldfish increases sharply as the temperature rises from 41°F. to 68°F.; remains constant at temperatures between 68°F. and 86°F.; then drops sharply (probably) due to a decrease in the metabolism available. Fishes seek an optimum temperature and tend to concentrate there according to several authors (Dendy, 1945, 1946; Buck and Cross, 1952; Brett, 1944; Fry and Hart 1948a, 1948b; Welch, 1952). Pearse (1939) believed that temperature is probably the main factor in determining the hydroclimate of a lake.

Fishes normally become acclimated to temperature changes but the rate of acclimation varies with the original temperature of the water. Acclimation from 39°F. to 54°F. takes 20 days; from 54° to 68°F. takes 7 days; while changing from 68° to 82°F. takes only three days (Brett, 1944). Acclimation is more rapid from low to high temperatures than from high to low temperatures (Hart, 1945; 1947; Brett, 1946). One is led to wonder what a fish does in moving from the surface of a pond at 87°F. to a twelve-foot depth where the temperature is 53°F. as described in a previous paper (Wallen, 1952a).

Any fish which lives in a farm pond is subjected to seasonal and sudden changes in temperature. If a fish selects an optimum temperature it is restricted in vertical movement to a thin layer of water. Many other factors, such as lowered oxygen, paucity of food, changed pH, plant growth, etc., add further complications to determinations aimed at evaluating these problems.

HYDROGEN-ION CONCENTRATION: The pH of the water was variable in the ponds during the study. The only set pattern was vertical, however, no systematic and continuous seasonal series of readings were taken for the same pond. The pH in ponds in Muskogee County varied from 5.4 at a 10-foot depth to a surface reading of more than 10.6 (inadequate indicators made it impossible to read beyond this figure). In Payne and Oklahoma Counties, no reading higher than 9.8 or lower than 6.4 was taken. Commonly the summer readings in ponds of Muskogee County revealed a lower pH reading by 0.1 or 0.2 units in the middle than at the bottom of the ponds, but the trend was always toward a decrease in pH reading with increased depth. The number of pH readings taken in ranges of depth and the average pH at those depths throughout the study are listed in Table 2.

TABLE 2.—THE NUMBER OF pH READINGS TAKEN WITHIN DEPTH INTERVALS AND THE AVERAGE pH READING FOR EACH INTERVAL

No. of Readings	Depth in feet	pH Reading
101	0–2	8.2
67	3–6	8.0
80	7–11	7.4
76	12–25	7.3

The readings were made immediately on securing the sample because the pH would change rapidly in a small container. This was also noted by Philip (1927) and Swingle (1947).

The pH at the surface of impounded waters varied seasonally in several states as follows: 7.1 to 8.0 in Kansas (Ratzlaff, 1952); 7.0 to 9.5 in Alabama (Swingle, 1947); 6.3 to 8.5 in Ohio; and 7.7 to 9.1 in Iowa. Nursall (1952) records a pH of 7.4 in Barrier Reservoir, Alberta. Moore (1952) studied natural waters in Louisiana with a pH value of 5.6 to 6.6. In all of these waters, the presence of fishes was important and the hydrogen-ion concentration did not seem to be a limiting factor to their occurrence or distribution.

Studies have been undertaken to establish the fact that fishes can undergo rapid changes in the pH of their environment without obvious ill effects. Tests with green sunfish, bass, goldfish, and bluegills indicate that changes from 6.1 to 9.5, from 8.6 to 6.0, from 9.3 to 6.6, etc., are not harmful (Wiebe, 1931a; 1931b). Many authors have noted that a higher pH than 7 is desirable for productivity (Wiebe 1931b; Rawson, 1939; Dexter *et al.*, 1942; Neess, 1949). European workers have maintained high fish production in waters with pH of 12, have established that acidity impedes recirculation of nutrients, have found tolerance to parasites greatly reduced at pH 5.5, and have found that fish die at pH 4.5 (Neess, 1949).

It would seem that the pH of the typical Oklahoma farm pond is probably not a limiting factor to productivity of fishes as it is usually recorded.

FREE CARBON DIOXIDE—The free carbon dioxide gas in ponds is an important constituent because of its effect on pH and turbidity as well as because of its commonly known effects on organisms. Irwin and Stevenson (1951) stated that a rough correlation exists between the occurrence of CO_2 and precipitation of colloidal clay. McCay (1925) claimed that fish are poisoned by CO_2 when decaying organic matter gets into the water after a heavy rain. Early studies by Birge (1907) showed that CO_2 is retained in acid waters and released to plants, even in alkaline waters, and that such alkaline waters are advantageous to plants as a source of carbon dioxide. Birge also stated that in an abundance of O_2 no gas other than CO_2 is produced in appreciable quantities. Several authors (Smith, 1933; Prescott, 1939; Burr, 1941; Swingle, 1947) have indicated that in most waters the limiting factor of most importance to photosynthesis is carbon dioxide.

The quantity determinations of free CO_2 dissolved in the ponds of Oklahoma are summarized in Table 3. Free carbon dioxide was present in relatively large quantities in most waters, especially at the greater depths.

TABLE 3.—THE NUMBER OF FREE CARBON DIOXIDE READINGS TAKEN WITHIN DEPTH INTERVALS AND THE AVERAGE FREE CARBON DIOXIDE READINGS FOR EACH INTERVAL

No. of Readings	Depth in feet	Free CO_2 in ppm.
78	0–2	0.9
60	3–6	4.2
75	7–11	8.0
68	12–25	16.9

The free CO_2 readings varied between 0.0 and 2.5 ppm at the surface and between 0.0 and 150.0 ppm at the bottom of Oklahoma ponds. In Kansas, CO_2 variations were between 0.0 and 25.0 ppm (Ratzlaff, 1952). Moore (1952) in Louisiana found that quantities varied from 1 to 10 ppm at the surface and were as high as 63.5 ppm at the bottom. Wiebe (1930) found a CO_2 maximum of 12.64 ppm in Iowa ponds. It is difficult to evaluate the effects of a relatively large CO_2 content on organisms. Swingle (1947) discussed the problem at some length and was convinced that most CO_2 values used in discussions are worthless since they vary too much with the time of day in which the sample was taken, the pond from which the sample was taken, the depth of the water, the method of determination, and immediacy of observation after collection of samples.

The production of CO_2 by organic materials used as fertilizers was found to be a limiting factor in Alabama fish production (Swingle, 1947). However, after the first year of fertilization, moderate use of inorganic fertilizers produced good phytoplankton growth and a relatively high fish production (Swingle, 1947).

Carbon dioxide is important from the standpoint of its relation to excretion since a fish cannot excrete CO_2 by osmosis when the CO_2 concentration is higher outside than inside the body membrane. At relatively low temperatures, the presence of excess CO_2 in the blood speeds the release of O_2 from oxyhemoglobin and thus reduces the O_2 carrying capacity of the blood (Matthews, 1921).

In some Oklahoma ponds the CO_2 content is high enough to become a problem to the deeper dwelling fishes. In most of them the CO_2 content would seem to be less a problem to photosynthesis than to the animals in the deeper areas.

DISSOLVED OXYGEN—A great variation in dissolved oxygen content was expected in farm ponds inasmuch as the temperature changed seasonally. It is perhaps surprising that the change in oxygen content with depth throughout all seasons was sufficient to produce layering of oxygen content in ponds throughout the year. The number of readings at each pond level and the average oxygen content of the water are listed in Table 4.

TABLE 4.—THE DISSOLVED OXYGEN CONTENT OF SOME OKLAHOMA PONDS AT DIFFERENT LEVELS OF DEPTH WITH THE NUMBER OF READINGS WITHIN EACH DEPTH LEVEL

No. of Readings	Depth in feet	O_2 in ppm.
73	0–2	9.3
64	3–6	6.8
80	7–11	4.0
72	12–25	2.5

Dissolved oxygen varied in quantity from 3.0 ppm to 32.3 ppm at the surface of the water and was as high as 12.0 ppm at the bottom. However, the reading taken just above the bottom was most commonly 0.0 ppm or quite close to this figure. Oxygen was entirely absent in several ponds with a maximum depth of as little as 4 feet during the summer. In one 4-foot pond in Eastern Oklahoma, oxygen was supersaturated (126%) at the surface and absent at the bottom at the same time.

As compared to these figures, oxygen at the surface averaged 9.9 and varied from 2.6 to 18.0 ppm in Kansas (Ratzlaff, 1952). In Ohio it was found (Roach and Wickliff, 1934) that during the day, in vegetation-choked ponds, the oxygen was 5.5 ppm in open water, 4.3 ppm in water choked with submerged vegetation, and 0.2 ppm in water choked with submerged vegetation and covered with emergent vegetation (due to the extra consumption of oxygen by plants at night there was oxygen depletion, some fish kill, and elimination of some potential food organisms). Moore (1952) found that Lake Chicot had no oxygen in the lower thermocline after the end of April while the surface varied from 60 per cent to 110 per cent saturation. Supersaturation in vegetation-choked ponds was common in an Ohio study (Schultz, 1952). Nursall (1952) found no oxygen stagnation in Barrier Reservoir, Canada, with the lowest percentage saturation at 53 per cent. Oxygen content as high as 18.7 ppm was quite satisfactory for fishes when experimentally tested by Moore (1952).

Controversy exists and experimental data differ greatly concerning the ability of fishes to withstand low oxygen content in water. It has been stated that "20 to 30 per cent of normal value of oxygen kills" fishes in ponds and streams. Rotting leaves and other organic matter that are washed into streams remove oxygen and kill fishes (McCay, 1925; Trautman, 1933). Organic materials lead to a multiplication of bacteria thus depleting the oxygen supply (Trautman, 1933). Moore (1942) found that "only where O_2 exceeds 4 ppm is there reason to believe adequate oxygen is available to the yellow perch." Moore states that at low concentrations of oxygen, small fishes can survive by using a thin film of oxygen rich surface water. Pennak (1944) believed that no factor was more important in the migrations of microscopic animals than the oxygen content of the water. Damage to fishes is recorded by Trautman (1933) from removal of O_2 by high temperatures in the waste water from milling steel and transformer stations.

On the other hand, many experimenters have observed apparent discrepancies. Some species of Protozoa such as *Stentor coeruleus* became abundant in anerobic situations (Sprugle, 1951). Ball (1950) found after heavy fertilization that the oxygen was 0.3 ppm but that no fish died. Fishes can tolerate oxygen concentrations lower than usually regarded as lethal (Cooper and Washburn, 1949). Swingle (1947) found that adult bluegills were not all killed until the oxygen fell to 0.1 ppm. Byrd (1952) indicated that oxygen concentrations less than 0.4 ppm are critical to bluegills and that these fishes "could not efficiently utilize the colder and deeper waters (of ponds) because of low concentrations of dissolved oxygen and high concentrations of CO_2 (3.3 ppm of free CO_2). The usual critical depth during the period from June 24 through September 12, 1949, in a two-acre pond was approximately 5 feet. Critical depth in a 22-acre pond was 7 feet probably due to wave action." Wiebe, *et al.*, (1934) found that six species of fish tested could withstand levels as low as 0.4 ppm of oxygen. Irwin and Stevenson (1951) noted that there was no fish kill in a small pond even though the oxygen stayed at less than 1.8 ppm (usually 0.0) for 18 days.

Most authors agree that plant photosynthesis is a very important source of oxygen in water. Wiebe (1930, 1931c) recorded data which showed a daily increase from 1.66 to 16.9 ppm and from 4.7 to 21.1 ppm of oxygen and believed that increases are roughly proportioned to the amount of algae present. Birge (1907) stated that lakes may have the inhabitable area doubled by the production of plant oxygen.

The yield of oxygen by plants in Wisconsin waters was found to vary but to be most effective at the 16- to 20-foot depth in most transparent waters and at about the 1-foot depth in colored waters (Juday and Schomer, 1935; Schomer and Juday, 1935). Meyer and Heritage (1941) found that the photosynthetic rate was as rapid at 31-foot depth in Lake Erie as it was at the surface, but stated that the photosynthetic rate never increased with depth. Swingle (1947) found a higher concentration of algae and

of oxygen at 2½ feet than at the surface of the water. Oxygen production in sunlight decreased between 11:00 A.M. and 3:00 P.M. on sunny days (Schomer and Juday, 1935).

Oxygen consumption is less per fish when several fishes are present than when only one fish is in a container (Wiebe, 1935). Wiebe and Fuller (1933) stated that any chemical change involving use of oxygen will be increased between two- and three-fold for each 10°C increase in temperature.

Different sizes of several species of fish can tolerate large and sudden changes in the concentration of oxygen in either direction. Wiebe (1931b) found that removing a fish from water with 5.6 ppm into water with 40.3 ppm and that transferring a fish from water with 41.0 ppm to water with 7.3 ppm were seemingly not harmful to fishes although the respiration rate was slower with the higher concentration of oxygen.

It would seem, therefore, that dissolved oxygen, though highly variable, is probably not directly limiting to fishes in Oklahoma ponds.

ALKALINITY — Carbonates, bicarbonates, and hydroxide alkalinities were indicated by titrating a sample of water with 0.02 normal H_2SO_4 while using phenolphthalein and methyl orange as indicators. Information concerning alkalinity of this type is desirable, primarily because of its relationship to the available CO_2 for photosynthesis and because of its use as an indicator of productivity. This type of alkalinity is closely related to pH and free CO_2 in the water and confirms or disputes the accuracy of other data. The alkalinities tested in Oklahoma waters by these methods are listed as Table 5.

TABLE 5.—ALKALINITY OF OKLAHOMA POND WATERS AS INDICATED BY END POINT DETERMINATIONS OF PHENOLPHTHALEIN AND METHYL ORANGE INDICATORS

Depth in feet	No. of Readings	Average Phth. Alk. in ppm.	No. of Readings	Average M.O. Alk. in ppm.
0–2	70	0.9	70	87.0
3–6	55	1.1	61	93.0
7–11	79	0.4	78	81.0
12–25	66	0.3	70	114.0

As shown in the table these alkalinity readings are not especially high. Phenolphthalein alkalinity varied from 0.0 to 4.3 ppm as compared with none in Alabama (Swingle, 1947), 0.0 to 38.9 ppm in Iowa (Wiebe, 1930), and 0.0 to 26.0 in Kansas (Ratzlaff, 1952). Methyl orange alkalinity varied from 5.0 to 233 ppm in Oklahoma ponds as compared to a variation from 50 to 395 ppm in Kansas (Ratzlaff, 1952) and from 14.0 to 38.5 ppm in Alabama (Swingle, 1947).

Alkaline waters increase the speed at which oxygen will combine, and the amount of oxygen used by fishes (Wiebe, *et al.*, 1934; Swingle, 1947). As indicated in the section on free carbon dioxide, higher alkalinities than are found in the waters studied are probably desirable.

LIGHT PENETRATION — The secchi-disk visibility in Oklahoma ponds was determined on 132 occasions and averaged 2½ feet. The maximum reading secured was 7 feet and the minimum was about ¼ inch (in muddy water). These readings point to the fact that even relatively "clear" waters in Oklahoma are not as transparent as are most northern waters as summarized in Welch (1952). In clear waters in Wisconsin, Birge (1913) determined that stained water absorbs energy faster than turbid water. Insufficient data are available for comparison in this area, but, general observations seem to agree with Birge's statement. Both turbid waters and stained waters are the cause of the low secchi-disk readings. According to Birge (1913) (in clear lakes) "not more than 20% of the sun's energy present at the surface is found at a depth of one meter." The absorption of the sun's energy is probably mostly completed in the first three feet of depth in Oklahoma ponds.

Many fishes depend on light for the location of food (Bigelow and Welch, 1924; Schneberger and Jewell, 1928) and can see with a minimal amount of light (at 1400-foot depths in the Sargasso Sea and at depths of 360 feet in Crystal Lake, Wisconsin, according to Clarke, 1936). However, the interference with light penetration by suspended or dissolved materials must make it difficult for the fishes to find food. Schlagel and Breder (1947) state that eyed fishes use more oxygen in the dark and this also may be a factor in the productivity of naturally darkened turbid waters.

The studies of the rate of photosynthesis (Juday and Schomer, 1935; Schomer and

Juday, 1935; Meyer and Heritage, 1941, etc.) suggest that lack of light penetration should reduce the effective depth limit of photosynthesis in Oklahoma ponds and thus lower the productivity.

TURBIDITY—During this study, a total of 353 records of turbidity were made. One hundred and fourteen of these readings were of pond waters with less than 25 ppm turbidity, while the other 239 readings averaged 113 ppm of silt-clay turbidity. The maximum pond record included in this study was 530 ppm. Irwin (1945) lists a maximum pond reading of 1,800 ppm. No attempt was made to select especially turbid ponds for these records.

Local interest in clean and muddy pond waters has been intense. Information has been secured on turbidity coagulation (Irwin, 1945; Irwin and Stevenson, 1951). Data have been collected on the direct effects of turbidity of fishes (Wallen, 1951b); on temperature-turbidity relationships (Wallen, 1952b); and of turbidity relationships to bottom fauna populations (Hambric, 1953). Some information is embodied in the long term effects of turbidity on populations in a thesis by Leonard (1950). Additional work is underway on turbidity-bacteria and turbidity-pollution relationships.

Although turbidities of 20,000 ppm produced effects on fishes and a turbidity of 200,000 ppm will usually kill fishes (Wallen, 1951b), these turbidities are not normally encountered in a pond. It has been found that bullfrog tadpoles and crayfish can also withstand over 150,000 ppm of turbidity without death, at least under certain laboratory conditions.

As turbidity studies proceed, the effects of the 1945 work (Irwin, 1945) are being observed throughout the area. Many turbid ponds have been cleared with organic matter and more are being changed from their original state of permanent silt-clay turbidity to a more transparent condition, for esthetic, fishing, or stock-water purposes. Although all of the work in this paper concerns normal farm ponds in use as such, it appears that the clarification process may someday resolve the problem of managing turbid waters to an academic one involving only test-area materials.

PLANKTON — Plankton populations of Oklahoma ponds are variable. The number of individuals per liter ranged from 1,184 to 365,883 in the eight samples counted. The plankton population obviously contributed to the turbidity of some waters but inadequate data were collected to determine the specific conditions involved in its presence. *Microcystis* was identified as the most abundant organism in some of the less productive ponds, while *Chlamydomonas* was the most common plankter of the pond with the highest plankton count. Only summer collections were made and no pattern of abundance was evident.

Plankton as a constituent of productivity is important in many ways. In various especially fertile ponds, the obvious indication of such productivity was a surface scum composed mainly of *Euglena*. Such a scum was noted on minnow ponds near Perkins and near Muskogee, Oklahoma, as well as at Stoutland, Missouri, and in a pond at the Naval Air Station, Jacksonville, Florida. Swingle (1947) discussed such scums and believed that the most desirable condition was present when about 1/3 of the pond was covered. The scum noted here varied with amount of clouds, time of day, and directly with the amount of fertilizing material added.

In his discussion, Swingle (1947) noted that organic fertilizers produce filamentous algae and inorganic fertilizers produce plankton algae. This rule does not hold locally, but, rather the appearance of such algae seems to be correlated with temperature conditions. Filamentous algae do especially well in winter and early spring and are mostly killed in the summer, often being replaced by plankton algae.

Moore (1952) observed that plankton was more concentrated near the bottom of the ponds he studied and this phenomenon was of special interest in the present studies. Huge concentrations of plankton—both plant and animal species—were found at the bottom of several ponds in late July, (Wallen, 1952a). This plankton was found in oxygenless water. Insufficient time was available to study its relationships, but it is suspected that a close balance existed, whereby production of oxygen by plants equalled the use of oxygen by animals in the population.

Schultz (1952) mentioned that when algae covered the surface of a pond the rate of evaporation was increased. It is possible that such a scum on a "producing" minnow pond would aid in evaporation and thus aid

in cooling the water at times when otherwise lethal temperatures might be reached.

BOTTOM FAUNA — Only a few scattered bottom-fauna determinations can be included in this paper. Burris (1954) and Hambric (1953) have studied phases of the problem in the area and have more complete information.

Bottom-fauna populations counted during this study were as high as 390 individuals per square foot. This compares with a population of 100 to 235 per square foot in four Michigan lakes (Eggleton, 1935) and would indicate that there is no paucity of bottom organisms. Dipterous larvae, especially Tendipedidae and Annelids (especially Tubificidae) were abundant with mostly Ephimeroptera and Odonata as the other insect forms captured. Unionid mussels of the species; *Anodonta corpulenta, Uniomerus tetralasmus* and *Carunculina parva,* were common. Sphaerids were represented by the genera *Musculium, Sphaerium,* and *Pisidium* with the first listed being most abundant. Snails of three genera were common. Three *Physas—P. anatina, P. halei,* and *P. hawnii* were present; *Helisoma trivolvis* and *Gyraulus parvus* are common, the latter species was found only where there was abundant higher aquatic vegetation.

AQUATIC FLOWERING PLANTS—During the last 10 years a notable change has occurred in the abundance of higher aquatic plants. During the last 8 years, especially, with the advent of the clearing technique (Irwin, 1945) and recognition of a definite niche for the plants, they have been allowed to increase in numbers. The effect on the fauna has been startling. Many damsel fly species, 5 species of snails, certain dragonfly and mayfly larvae, and water mites have been collected where they did not exist before. Certain of the pond weeds; *Potomogeton, Najas, Jussiaea,* and *Myriophyllum* are especially common and have made conditions more favorable for other plants. A need has developed for better control measures for cattails and water lilies, as well as for the other plants mentioned.

There is no doubt that these plants are desirable at least to a limited degree. They serve the functions of (1) providing a fertilizer to clear the water, (2) serving as food for invertebrates, and (3) adding oxygen to ponds that are protected from the wind. Schneberger and Jewell (1928) found that the presence of vegetation was correlated with increased fish production and several studies have been made to establish the fact that flooded areas with their vegetation add to fish production (Ellis, 1931; Irwin, 1945; and Irwin and Stevenson, 1951). Various textbooks have listed aquatic plant uses including (1) breeding sites for fishes, (2) protection for young fishes, (3) human food, etc., along with those functions mentioned above.

Although Tarzwell (1936) found that most aquatic plants in Michigan had sufficient means of dispersal to occur naturally where conditions were suitable, there is perhaps a need for aquatic plant seeding in many newly impounded waters in the Southwest.

CONDUCTIVITY — Much variation was found in the conductivity of the waters of ponds. Readings were found between 3,600 and 48,800 milliamps. The average conductivity readings are listed in Table 6.

TABLE 6.—CONDUCTIVITY READINGS TAKEN AT DIFFERENT DEPTHS IN PONDS IN OKLAHOMA

No. of Readings	Depth in feet	Average Conductivity in Milliamps
33	0–2	18,000
29	3–6	18,000
31	7–11	22,000
23	12–25	12,000

DISCUSSION

Several factors have been demonstrated to be important considerations in the construction of a pond. One of the rules (Welch, 1952) for determining the productivity of a body of water is a long shoreline in comparison to its volume. Several pond builders have found that the square pond is less productive than an irregularly shaped pond. Oxygen is sometimes entirely lacking at depths below 4 feet in Oklahoma. Therefore it is desirable to have a considerable area of the pond (approximately one-third seems to be satisfactory) with the depth not more than 4 feet. Deeper waters are also desirable since they do not fluctuate greatly in temperature and aid in the maintenance of water levels during periods of low rainfall and high evaporation. In the Southwestern states, where rainfall is sporadic and evaporation is great, it would seem desirable to

build ponds with about one-half of the water area more than 12 feet in depth.

The type of soil in the watershed is important in determining the management procedures to be followed. The soil in Central Oklahoma is mostly clay of Permian Red Bed origin with a considerable portion composed of very fine clay (Wallen, 1951b). This clay not only remains suspended as turbidity but serves as an effective pond seal wherever it appears. It has sufficient nutrients to supply the basic plant needs, although it is easily eroded by water. In Eastern Oklahoma the clay particles are larger and do not tend to remain suspended in the ponds.

Water-level control is especially important in the Southwest. Rainfall is sometimes torrential and often infrequent. If the water can be retained in a pond, it becomes much more productive year by year as photosynthesis of plants and metabolic products of plants and animals are added. It has been found desirable to prevent water exchange by any means practicable, such as bypass ditches or terraces, special drainage devices, and watershed control either by vegetation or limiting the drainage area. A pond should be so located that water level can be managed. It should not be located on a flowing stream, if maximum productivity is desired.

Ponds should be constructed with provisions for draining. More effective harvest of organisms, better control of desirable or undesirable population growths, better flood protection, etc., are possible if ample drain pipes are provided to remove all the water from the pond in a short time.

Some ponds receive run-off water from farm barnyards and pastures, or sewage drainage from domestic uses. These materials add to the fertility of the water to increase productivity (Sawyer, 1947). Although plankton and fish production were found to be not correlated in one study (Schneberger and Jewell, 1928), it seems to be more universally agreed (Wiebe, 1930; Sawyer, 1947; Neess, 1949; Welch, 1952) that a sizeable plankton population is desirable, especially in minnow ponds. Algae populations may be a nuisance in instances of over-fertilization by causing odors, scums, unsightliness, and by interfering with water usage, but they aid productivity by producing oxygen in areas where oxygen is critical. Algae-produced oxygen is often an important factor in supplying the needs for sewage reduction in parts of the state.

Aquatic plants are especially important in Oklahoma ponds. Oxygen production, recirculation of otherwise buried nutrients, provision of food for aquatic animals, and many other useful purposes are served by the living vegetation. Decaying vegetation provides the organic matter needed for production of animals, and for coagulation of soil turbidity. The higher plants compete directly with algae for nutrients and are mutually controlling (Swingle, 1947; Hasler and Jones, 1949). However, the conditions during their greatest competition are the best for productivity. If the pond is clear enough, it will become inhabited by aquatic plants distributed by natural forces, however, in some cases it has proved desirable to hasten their appearance by plantings. The decaying plants will tend to fill the pond more rapidly, but they will contribute fertility during the time of their existence.

Artificial lakes are as capable of producing small organisms as natural lakes (Roach, 1933). It has been found in Oklahoma that the maximum growth of fishes occurs during the first year of water impoundment (Buck and Cross, 1952). Burris (1954) found that a new pond contains a bottom fauna soon after impoundment. Pond water usually floods terrestrial vegetation that decays to release organic matter, settle the suspended soil, and provide fertility for plankton production. The fertilizing effects are felt throughout the food chain but most rapidly through those organisms that are near the base of the chain (Ball, 1949).

Ponds that are subject to fluctuations from evaporation or use of the water may have a limited bottom fauna. The deeper portions of some ponds are restrictive to many bottom forms due to the paucity of oxygen in the summer. Soil, suspended in erosion water, is sometimes carried into ponds and may plug the breathing apparatus or destroy many bottom organisms (Ellis, 1936).

Hasler (1947) has stated that the cardinal principle of the reservoir manager is to maintain the reservoir in service to man. The management of Oklahoma ponds has successfully involved all of the following techniques, usually in combination of two or more of the practices: (1) the pond is drained and restocked, (2) a portion or all

of the pond water is poisoned, (3) the water level is fluctuated, (4) special harvesting techniques are used, (5) the water is fertilized by organic or mineral fertilizers, (6) the bottom is planted to aquatic vegetation, (7) chemicals and organic matter are added to clarify the water, (8) special devices are used to aerate the water, (9) terracing, ditching, or other water bypass methods are provided, (10) predator, parasite, and competitor control is attempted, (11) alternate dry fallowing and refilling procedures are used in the already tight soil, and (12) various units of the population may be favored to bring about the control of other populations of plants and animals. The basis for the success of these management procedures and the selection of techniques for use should be derived from the limnological conditions of the particular pond involved.

SUMMARY

1. Data are given concerning the limnological conditions of 59 ponds in Payne, Oklahoma, and Muskogee Counties of Central and Eastern Oklahoma. A total of 4,306 individual records are summarized.

2. The temperature data reveal a consistent layering of the water with a permanent thermocline evident only during April, May, June, and July. The bottom waters are warmer than they would be at maximum density, but reverse stratification is evident during December and January. Although warm temperatures are evident at the surface in the summer, an aquatic organism could select cooler water with increasing depth.

3. There is definite stratification of the water into chemically different layers. The hydrogen-ion concentration decreases toward the bottom. Free carbon dioxide is abundant at lower levels in the pond. Oxygen is markedly less abundant near the bottom.

4. Oklahoma waters had average to lower alkalinities than have been recorded in the literature indicating a slightly lower productivity potential.

5. Turbidity is an obvious condition in many impoundments. Its direct effects may be few, but the indirect effects of its presence are many.

6. Aquatic plants that appear in clear and cleared waters seem to be beneficial, although their control may be a problem.

7. Some management procedures for aquatic animals have been suggested from application of the data.

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ANALYSIS OF MUSKRAT AGE DETERMINATION METHODS AND THEIR APPLICATION IN MICHIGAN [1]

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The muskrat, *Ondatra zibethica*, has received much attention, due primarily to its value as a fur resource. However, muskrat trapping seasons vary greatly throughout the United States and aging methods that are reliable in some areas might not be applicable to other states during legal trapping seasons. In an effort to establish "yardsticks" for southern Michigan populations, biologists at the Rose Lake Wildlife Experiment Station examined 425 muskrats (328 juveniles, 97 adults) during the last five years in an attempt to determine which aging method would prove most valuable. Several important facts were evident. The purpose of this paper is to summarize the findings.

Procedure

All muskrats were taken on the station in the legal trapping season, December 1–31, 1949–1953. All were examined and weighed in the station laboratory. Sex and age were first determined from the external genitalia. Each muskrat was then marked with two tags that would later identify the pelt and carcass. After skinning, the carcass was examined internally. Length and width of testes were measured, and the uteri were examined for placental scars. Zygomatic breadth, and width of upper incisors were noted. Pelts were divided into age and sex classes according to degree of primeness of the pelt and presence or absence of nipples.

In order to test the reliability of various aging methods it was necessary to arrive at a positive age for each animal. Usually age was easily determined, with all criteria in agreement. However, in the few borderline cases, age was arbitrarily assigned on the basis of predominant evidence. Histograms of the measurements were prepared. From these data dividing points most accurately separating adults from juveniles were determined. In the "overlap," an age ratio of approximately three or four juveniles per adult, corresponding to the age ratio of 338 juveniles : 100 adults found by combining all data, was maintained.

Each aging method that utilized measurements was subjected to statistical analysis. The means and standard error for each distribution were calculated (Table 1). Mean measurements found for each age class were compared by the *t* test, and significant differences at the one per cent level were noted.

Table 1.—Measurements Used to Determine Age of Rose Lake Muskrats

	JUVENILES					ADULTS					
	No. in sample	Min.	Max.	Mean	S.E.*	No. in sample	Min.	Max.	Mean	S.E.	Total
Incisor width (mm.).....	164	5.8	8.0	6.9	±.04	49	7.1	9.4	8.1	±.07	213
Penis diameter (mm.).....	168	2.9	5.9	4.4	±.04	50	4.9	8.0	6.3	±.06	218
Testes length (mm.).....	164	6.6	14.9	9.2	±.12	47	8.0	20.6	14.4	±.45	211
Weight (g.).....	312	423	1307	953	±7.81	91	934	1572	1267	±14.15	403
Zygomatic breadth (mm.)..	212	31.8	42.0	38.0	±.10	68	39.0	44.3	41.4	±.16	280

* Standard error of the mean.

Results

Width of Upper Incisors: Measurements

[1] A contribution from Pittman-Robertson Research Project W-40-R, Game Division, Michigan Department of Conservation.

The author wishes to thank biologists at the Rose Lake Wildlife Experiment Station who assisted in gathering data used for this paper and Dr. C. T. Black, biologist in charge of the station, for his helpful suggestions and assistance during the study.

of the upper incisors at gum line appeared least reliable of the aging methods tested. This method, described by Sooter (1946), accurately aged 83.1 per cent of 213 muskrats, using 7.4 mm. as the lower limit for the adult age class. Although the means were significantly different, considerable overlapping of measurements between age classes occurred (Fig. 1). Perhaps better accuracy

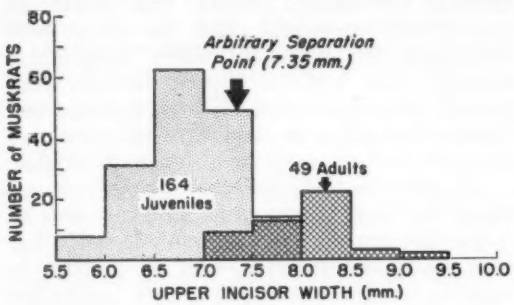

FIG. 1. Distribution of upper incisor measurements.

could have been obtained by measuring incisors near the "cutting edge," as some difficulty was experienced in determining the gum line on the skinned carcass. Several biologists autopsied muskrats in the sample and measurements on individuals varied according to the interpretation of the gum line. When it became apparent that these variations were occurring, a test was evolved to determine the source of error. Six biologists measured incisor width at the gum line and at the cutting edge, on three skinned carcasses. The cutting edge measurement was less variable and suggests a possible improvement in this aging method.

WEIGHTS: As expected, the weight of the muskrat, although indicative of age, did not yield satisfactory aging data. Considerable overlapping of age classes occurred (Fig. 2).

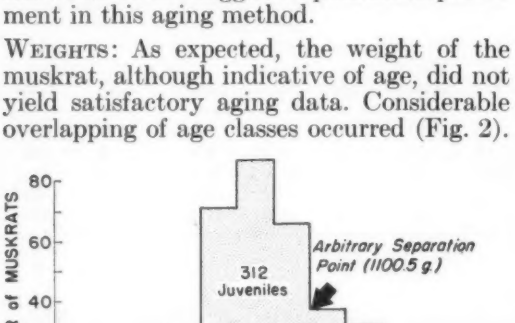

FIG. 2. Weight distribution of Rose Lake muskrats.

Adult muskrats averaged 1,267 grams compared to 953 grams for the juvenile animals, a significant difference at the one per cent level (t test). A total of 85.8 per cent of 403 animals were correctly aged using 1,100 grams as the upper limit for the juvenile age class.

ZYGOMATIC BREADTH: This method, described by Alexander (1951), correctly aged 88.6 per cent of 280 muskrats. Using the measurement taken across the skull at the zygomatic arches immediately after skinning, 39.7 mm. was selected as the lower limit for the adult age class. Alexander (1951), used 40.6 mm. as the dividing point between age classes in a January sample. Comparing the two age classes, the mean zygomatic breadth of the adults was significantly greater than the mean breadth of the juvenile class. Distribution of the zygomatic breadth measurements are shown in Figure 3.

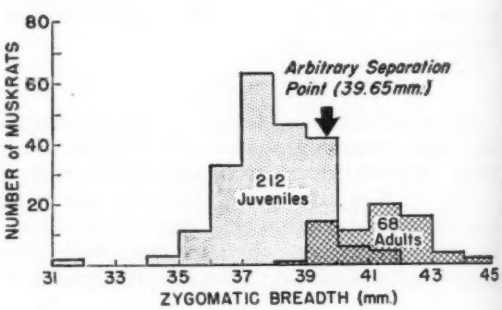

FIG. 3. Distribution of zygomatic breadth measurements.

TESTES LENGTH: Errington (1939) found that "Among practically all of the animals trapped in November and December, the young of the year could easily be distinguished from adults by macroscopic examination of testes. . . ." But, Alexander (1951) reported, "as the breeding season approached the variation between adults and subadults became smaller and the reliability of the method became greatly reduced." Testes measurements were accurate indicators of age at Rose Lake where all trapping occurs in December, well in advance of the breeding season. The average length of the testes of each male was calculated. Using 11.6 mm. as the upper limit for the juvenile age class, 90.5 per cent of 211 males fell in the correct age group. Comparing mean measurements

of each age class, a significant difference was found (Fig. 4).

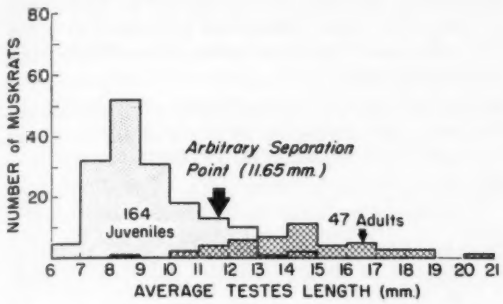

FIG. 4. Distribution of testes measurements.

PENIS DIAMETER: This method, described by Baumgartner and Bellrose (1943), proved very reliable for aging muskrats in the laboratory before skinning. Of 218 males examined, 94.5 per cent were correctly aged using a diameter of 5.1 mm. as the upper limit for the juvenile age class (Fig. 5).

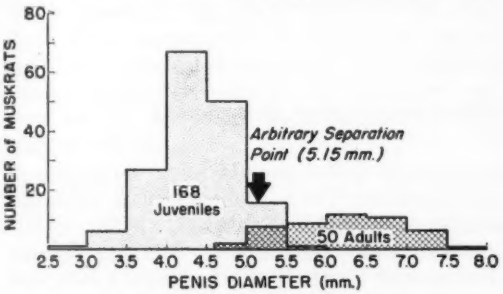

FIG. 5. Distribution of penis measurements.

Again a significant difference in means existed between age classes. Penis color and shape are excellent age indicators, as mentioned by Baumgartner and Bellrose (1943). If these characteristics are considered with the diameter, almost all of the male muskrats can be accurately aged.

VAGINAL ORIFICE: Baumgartner and Bellrose (1943) reported the juvenile females had a thick membrane covering the vaginal orifice. This membrane is usually absent in the adult; however, exceptions are found. Of 137 juvenile females examined, the vaginal orifice was open on only three. Five adults of 40 examined had thin vaginal membranes. The adult membrane usually can be identified as it ruptures easily if the urethral papilla is pressed gently forward. Basing aging on an open or closed vaginal orifice yielded 95.5 per cent accuracy in this study.

PELT PRIMENESS PATTERN: Applegate and Predmore (1947) and Shanks (1948) found that the primeness pattern on the flesh side of the pelt was an accurate age indicator during the fall and early winter. Prime areas are clear and unprime areas appear dark and demonstrate a pattern. Juveniles typically exhibit a lyre-shaped unprime area on the dorsal side of the pelt. The adult pelt shows no uniform primeness pattern and is mottled on the dorsal side. Of 381 muskrats (299 juveniles, 82 adults) from the Rose Lake Station aged by pelt primeness, only eight were placed in the wrong age classification, an accuracy of 97.9 per cent.

Sex can be determined by noting the presence or absence of nipples on the pelt. Pelt examination proved 100 per cent reliable as a sexing method.

PLACENTAL SCARS: Another excellent aging method described by Errington (1939) is the examination of the uterus. Although time-consuming, it proved accurate, and yielded information on production of young. No placental scars were located on juvenile uteri, and only one adult uterus failed to have scars. Apparently, barren adult females were nearly absent from the Rose Lake population during these years. Hence, aging by presence or absence of uterine scars yielded 99.4 per cent accuracy on examination of 170 females (134 juveniles, 36 adults).

TABLE 2.—RELATIVE RELIABILITY OF MUSKRAT AGING METHODS

Method	Per cent accuracy
Both sexes:	
Pelt primeness	97.9
Zygomatic breadth	88.6
Weight	85.8
Incisor width	83.1
Males:	
Penis diameter	94.5
Testes length	90.5
Females:	
Placental scars	99.4
Vaginal orifice	95.5

SUMMARY AND CONCLUSIONS

Biologists examined 425 muskrats trapped on the Rose Lake Wildlife Experiment Sta-

tion 1949–1953. Eight age determination methods were tested in an effort to determine which method would be most accurate and usable in Michigan (Table 2).

The pelt primeness pattern provided accurate age data. The method also has great utility as it is possible to examine a trapper's season catch, or large numbers of pelts at fur houses without the necessity of making daily contacts. If it is desirable to examine muskrats before skinning, the external sex characteristics should prove most reliable as age indicators. Internal age determination by testes and uteri, although accurate, are time-consuming. It is also necessary to examine the carcass soon after skinning.

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TRAP RESPONSE OF THE COTTONTAIL RABBIT AND ITS EFFECT ON CENSUSING [1]

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An examination of census methods was undertaken as a portion of a study of population dynamics of the cottontail rabbit (*Sylvilagus floridanus mearnsii*) at the Kellogg Station of Michigan State College near Battle Creek, Michigan. Special attention was given to the use of live-trapping data to estimate rabbit populations. A number of workers have used such data to estimate numbers of fish (Schnabel, 1938, Schumacher and Eschmeyer, 1943); insects, (Fisher and Ford, 1947; Jackson, 1948) and small mammals (Hayne, 1949). Rabbit populations estimated from trapping records in the present study using the method described by Hayne (1949), were found to be much lower than those estimated by determining the marked fraction in the population by shooting a sample as described by Allen (1938). This discrepancy suggested that the fundamental assumptions basic to the census techniques should be studied. One assumption upon which the use of trapping data is based is that a uniform probability of capture exists in the population. This paper deals with an examination of the variability of rabbit trap response and the effect of such variability on population estimates based on trapping data.

[1] Appreciation is expressed to the many people that aided in this investigation. Dr. George A. Petrides supervised this study which represents parts of a thesis in partial fulfillment of the requirements for the degree of Master of Science, Michigan State College. Biometrical analysis was carried out under the guidance of Dr. Don W. Hayne. Drs. D. W. Hayne, G. A. Petrides, A. E. Staebler, P. I. Tack, all of Michigan State College, critically read this manuscript. Field work was done while the author was in residence at the W. K. Kellogg Bird Sanctuary as holder of a W. K. Kellogg Fellowship. Dr. Arthur E. Staebler, Director of the W. K. Kellogg Bird Sanctuary deserves special thanks for assistance rendered the author while engaged in field work as do also Mr. C. M. MacCrary, Superintendent of the W. K. Kellogg Sanctuary, Mr. Walt Lemmien, Forester, in charge of the Kellogg Forest and Mr. Edward Caball, Foreman at Kellogg Feed Research Farm.

FIELD PROCEDURES

Trap response of rabbits was evaluated by considering live trapping data collected

during the fall and early winter of 1951 and 1952. Fifty wooden traps similar to those described by Hickie (1940) and 27 wire-mesh traps (Size 3, National Trap Company, Tomahawk, Wisconsin) were used. To ensure complete coverage, the main study area of 160 acres, largely surrounded by open, cultivated land, was divided into halves which were trapped separately in two trapping periods. In 1951, these periods extended from November 3 through 15 and from November 20 through December 10. In 1952, trapping was conducted from October 24 through November 5 and from November 6 through November 27. An irregular spacing of traps was used because an irregularly shaped lake in the center of the study area made the operation of a grid or a straight trap line impractical.

Rabbits were marked with numbered metal tags inserted near the center of each ear as described by Haugen (1942). There was no evidence of tags being lost except that an occasional one was torn out by shot. Trap location, age, sex, weight, and other data were recorded each time a rabbit was handled. Closely supervised hunting took place during December and January and the location at which each rabbit was shot was recorded.

HETEROGENEITY OF TRAP RESPONSE

If there is a uniform probability of capture among all members of a population or, stated another way, if each capture represents a random sample from the population, then the distribution of the number of times different members of the population are captured should agree with a Poisson or binomial distribution. The probability of capture represents the average likelihood that a rabbit will be caught on any particular night. For example, if a probability of capture of 0.2 exists, the chances are 2 in 10 that a certain rabbit will be caught on any night, or the rabbit will be expected to be captured twice in 10 nights. An estimate of average probability of capture may be computed by dividing the number of captures made on a trap line by the product of the number of nights the line was operated multiplied by the number of animals present.

In order to determine whether rabbits behaved as though characterized by a uniform probability of capture on the trap lines, the observed distribution of frequency of capture was compared to the expected binomial or Poisson distribution. Throughout this study Ricker's (1937) recommendation that the binomial distribution be used when a probability of 0.05 or greater exists and that the Poisson distribution be used with smaller probabilities has been followed. Frequency of capture of the rabbits caught is easily obtainable from trapping records. However, the frequency for the zero-capture category (the number of animals not captured) is not known exactly. Because of this, an analysis which considered only the known number of rabbits which were captured at least once was made. The expected binomial distribution of capture frequencies for this portion of the population was compared to that actually observed (Table 1). For both years

TABLE 1.—COMPARISON OF OBSERVED DISTRIBUTIONS OF CAPTURES OF RABBITS WITH EXPECTED RANDOM DISTRIBUTIONS FOR RABBITS CAPTURED AT LEAST ONCE

Number of Recaptures	1951		1952	
	Observed Number	Expected Number	Observed Number	Expected Number
0	35	11.0	42	5.6
1	12	23.3	14	15.8
2	6	23.1	4	21.2
3	11	13.8	6	18.0
4	8	5.7	3	10.9
5	3	1.7	2	5.0
6	0	.4	4	1.8
7	3	.1	1	.6
8	0	.0	1	.2
9	1	.0	0	.0
10	0	.0	1	.0
11	0	.0	1	.0

statistically highly significant differences existed, which indicated that the distribution of captures was not random.

In order to deal with the entire population in determining randomness of trap response, it was necessary to have an accurate estimate of the number of rabbits not captured. This could be done by adopting, as correct, the estimate of the total population based on the marked-unmarked ratio in the hunting kill, in the manner of Allen (1938). For this assumption to be valid, two requirements must be satisfied; 1) shooting must provide an unbiased sample from the population, 2) rabbit movement into and from the study area must be slight. Evidence to support the first point will be presented

later. The second requirement was believed to be especially well met during the 1951–52 trapping and shooting period when early, deep snows restricted rabbit movements to the dense cover of the main study area. It was noted that after a heavy snow cover had accumulated, traps located in open peripheral areas were no longer productive. Rabbit tracks in the snow indicated that their movements were confined to areas having woody cover and that they did not venture far into open areas. During the shooting period, over 100 hours of field observations failed to yield evidence, from tracks or location of shot rabbits, of movement to or from the study area.

Because the above assumptions are believed valid, the zero-capture category was computed as the difference between the known number of rabbits trapped and the total estimated population based on the marked-unmarked ratio in the hunting kill. The distributions of times captured including the computed zero-capture category are shown for both trap lines run in 1951 compared with what would be expected if a random trap response existed (Table 2). It is

TABLE 2.—COMPARISON OF THE OBSERVED DISTRIBUTIONS OF RECAPTURES OF RABBITS FOR TWO TRAPLINES WITH THE EXPECTED BINOMIAL DISTRIBUTIONS

Number of Captures	Trap Line "A"		Trap Line "B"	
	Observed Number	Expected Number	Observed Number	Expected Number
0.....	121	67.60	163	135.54
1.....	35	76.54	60	85.54
2.....	12	39.93	12	24.80
3.....	6	12.70	6	4.34
4.....	11	2.76	5	.63
5.....	8	.43	1	.43
6.....	3	.04	2	.03
7.....	0	.00	2	.01
8.....	3	.00	1	.00
9.....	0	.00	0	.00
10.....	1	.00	0	.00
Total.....	200	200	251	251

again apparent that more rabbits occurred in the zero and in the higher categories (3 and up) than would have been the case if a uniform probability of capture existed. Chi-square tests indicated that these differences were highly significant and therefore the distribution of captures was not random. Hence, the assumption that a uniform probability of capture exists, which is basic to current census methods in which only trapping data are used, has been shown not to apply to cottontails at the Kellogg Station. Several other workers have recognized nonrandom trap response in other species. Chitty and Kempson (1949) demonstrated that samples from a vole (*Microtus agrestis*) population, part of which had been marked, were not drawn at random. Young, Neess, and Emlen (1952) found that the house mouse (*Mus musculus*) displayed heterogenous trap response. DeLury (1951) recognized a nonuniform probability of capture as one of the problems in estimating fish populations by trapping and marking experiments.

In order to determine whether heterogenous trap response might be associated with differences in age, sex, or previous trap experience, the trapping data were arranged into elements grouped as to sex, age, and previous trap experience. The probability of capture was calculated for each group to determine whether the different population elements consistently had different probabilities of capture of the same direction and magnitude. Differences were found to exist but they were not consistent except in regard to trap experience. Once a rabbit was captured, it was more likely to be recaptured than a rabbit which had not been taken.

However, despite their inconsistencies, differences did exist and it would be probable that the distribution of recaptures in a sample made up by pooling the trapping data from several population elements which exhibited different probabilities of capture would not correspond to a simple binomial distribution even though the sampling within each population element had been at random. In order to find out whether this effect might explain the observed distribution on the basis of these sex and age elements, the following analysis was made. The theoretical expected fraction of the sample for each age and sex combination in each capture category was calculated (Table 3). These were then combined in the same ratio as the numbers of individuals in the various age and sex combinations. These weighted mean values (Table 3, line 5) were then compared with those obtained by calculating the expected binomial distribution on the basis of a single probability of capture for the entire population where the different ages and sexes were not considered separately (Table 3, line 6).

TABLE 3.—COMPARISON TO SHOW THE EFFECT OF COMBINING DATA FROM THE FOUR AGE AND SEX COMBINATIONS OF RABBITS

Sex and Age	Number Captured	Average Probability of Capture	Fraction of the Population Expected in Each Capture Category						
			0	1	2	3	4	5	6
Adult Male	5	.084	.320	.381	.210	.070	.016	.003	.000
Adult Female	9	.131	.161	.315	.286	.158	.060	.016	.005
Juv. Male	28	.084	.320	.381	.210	.070	.016	.003	.000
Juv. Female	27	.071	.384	.381	.175	.049	.009	.001	.000
Combined 5:9:28:27		.082	.331	.373	.202	.070	.018	.003	.000
Binomial Distribution		.082	.329	.386	.204	.064	.015	.002	.000

There was not a large enough difference between the two series of values to explain the large differences previously noted (Tables 1 and 2).

Further evidence that the discrepancy was not due to a random distribution of captures within each age and sex combination having a different probability of capture is shown when the distribution of captures within each age and sex group was compared with that which would be expected if the distribution was at random. Chi-square tests revealed significant differences in each instance. As with the combined data, too many individuals fell into the no-capture and many-capture categories. This demonstrated rather conclusively that the observed departure from random trap response could not have resulted from combining the data from animals of different age or sex.

Inspection suggested that the frequency distribution of captures on the trap lines might represent a compound distribution caused by combining population elements with different probabilities of capture. As an approximation of this, the 200 rabbits believed dealt with on Trap Line A were divided into three groups: 168 caught 0–2 times, 25 caught 3–5 times and 7 caught 6–10 times. The corresponding probabilities of capture for these groups were 0.027, 0.314, and 0.571, respectively. Three separate, expected

TABLE 4.—EXPECTED DISTRIBUTION OF RECAPTURES FOR A POPULATION OF RABBITS MADE UP OF ELEMENTS WITH THREE DIFFERENT PROBABILITIES OF CAPTURE, TRAP LINE A

Times Captured	Expected Distributions of Rabbits Observed to be Captured					
	(1) 0–2 Times (Poisson) p=.027	(2) 3–5 Times (Binomial) p=.314	(3) 6–10 Times (Binomial) p=.571	Sum of 1, 2, and 3 Average p=.082	Binomial p=.082	Observed in Data p=.082
0	118.2	.2	...	118.4	65.8	121
1	41.5	1.1	...	42.6	77.2	35
2	7.3	3.0	.0	10.3	40.8	12
3	.8	5.1	.1	6.0	12.8	6
4	.2	5.8	.2	6.2	3.0	11
5	.0	4.8	.6	5.4	.4	8
6	.....	2.9	1.1	4.0	.0	3
7	.....	1.4	1.5	2.9	....	0
8	.....	.6	1.5	2.1	....	3
9	.....	.1	1.1	1.2	....	0
10	.....	.0	.6	.6	....	1
11	.....	...	.2	.2	....	0
12	.....	...	.1	.1	....	0
Totals	168.0	25.0	7.0	200.0	200.0	200

distributions using these numbers and probabilities were computed, and are shown in Table 4, columns 1, 2, and 3. A combined distribution, formed by adding the corresponding frequencies from the three separate distributions, is shown in Table 4, column 4 along with the distribution computed for a single probability of capture. The observed distribution (Table 4, column 6) did not differ significantly from that obtained by combining the expected frequencies of capture for three population elements having different probabilities of capture. It did, however, show a highly significant difference when compared with a simple binomial distribution.

This analysis showed that the observed distribution of frequency of capture can be explained as a compound distribution, which reflects a variable probability of capture among members of the population. According to this view, most animals had a low probability of capture and relatively few had higher probabilities. The exact probabilities used in synthesizing the compound distribution in Table 4, are not to be viewed as necessarily biologically significant but rather as illustrating the fact that a compound distribution is a possible explanation of the observed distribution.

The question arises as to why some rabbits entered traps more readily than others. Three explanations can be offered for this phenomenon: first, some animals may have had a small home range within which a trap was favorably located to be encountered often; second, rabbits vary in an innate tendency to enter traps; and, third, once a rabbit has had some experience with traps its behavior is altered so that it is more likely to be recaptured. The number of trap locations at which all rabbits captured five or more times had been taken (Table 5) gives some indication of the validity of the first two explanations. Frequently captured rabbits turned up in many trap locations, thus discrediting the explanation based on the small home range in which a trap is favorably placed and supporting the view rabbits vary in an innate tendency to enter traps. Evidence which indicates that experience with traps induces a change in trap response was found when it was observed that the mean time interval between first and second capture was significantly longer than the interval between later captures. Other evidence which suggests that some rabbits become conditioned to entering traps was found when rabbit tracks were observed in the snow around sprung, unbaited traps after the trapping period had been completed. It seems plausible that past experience with traps was responsible for this behavior.

EFFECT OF HETEROGENEOUS TRAP RESPONSE ON POPULATION ESTIMATES

The above discussion indicates that census methods which assume a random trap response are based upon a false premise. This premise will probably cause estimates to be lower than the actual population because rabbits which have a high probability of capture tend to cause an unrepresentatively high previously captured fraction in each catch. This sampling bias makes it appear that a higher fraction of the population has been handled than is actually the case. With this supposition in mind, the trapping data have been examined in two different ways in order to measure the degree of error in estimates made in the manner proposed by Hayne (1949).

First, the extent to which heterogeneous trap response reduces the estimate below the true population number may be shown by estimating the number of shot rabbits from

TABLE 5.—NUMBER OF LOCATIONS AT WHICH FREQUENTLY CAPTURED RABBITS WERE TRAPPED

Rabbit	Number of Times Trapped	Number of Trap Locations
A	12	6
B	11	6
C	10	5
D	9	2
E	8	6
F	8	7
G	8	6
H	7	5
I	7	3
J	7	4
K	7	7
L	6	5
M	6	3
N	6	3
O	6	4
P	5	4
Q	5	4
R	5	3
S	5	5

their own trapping records. In other words, population estimates for the known number killed were made from the trapping records of these particular animals, many of which were not captured at all. In 1951, these estimates were 43 and 42 per cent of the number shot in the vicinity of Trap Lines A and B, respectively. In 1952, the estimates were 67 and 43 per cent of the numbers shot near the trap lines.

Second, the effect of non-random trap response may also be shown by comparing population estimates based solely on trapping data with those obtained from marked-unmarked ratio in the hunting kill. For the two trap lines in 1951, these estimates were 40 and 47 per cent of the number estimated from the shot sample. In 1952, trapping data estimates were 45 and 43 per cent of the total population estimates based on hunting data.

Thus, there is relatively close agreement in the degree of error (1) when estimating the known number of rabbits shot from the trapping records of that partial population, and (2) when estimating the total number present from all trapping records in comparison to the number estimated by means of the ratio of marked rabbits among the shot animals. This consistency of underestimation seems to indicate either that the estimates of population made from marked-unmarked ratio in the hunting kill are accurate or that a number of animals moved into the area between the trapping period and the hunting season. This last explanation is considered unlikely on the basis of the field observations and consequently the agreement in error shown above is interpreted as confirming the accuracy of estimates made after the manner of Allen (1938).

Haugen (1943) estimated rabbit populations by trapping until previously marked animals predominated in each day's catch. He then considered the number that had been captured as the total resident population. Later captures of unmarked rabbits were described as being transients, which were not part of the resident population. When this method was applied to data collected in this study, the population estimates ranged from 28 to 40 per cent of the number estimated from the tagged-untagged ratio in the hunting kill in the vicinity of trap lines.

Green and Evans (1940), used the tagged-untagged ratio in a second trapping period to estimate the number of snowshoe hares present. When this method was applied to cottontails in the present study, population estimates were far too low. Comparison has been made by estimating the population by using the average fraction marked for the last two days of trapping to represent the fraction of the population that had been previously marked. This estimate was then compared with that obtained by trapping and shooting. Once again the estimated number was only about 40 per cent of the number probably present. It is apparent that where trap response is heterogeneous, population estimates which depend upon a second large sample by trapping were just as inaccurate as those in which each day's catch is given consideration in making the estimate.

SUMMARY

Rabbits were found to display heterogeneous trap response as indicated by the fact that many rabbits had a relatively low likelihood of capture whereas a smaller number were frequently captured. Rabbits captured many times were caught in many different locations which suggests that frequent captures were not due to having a small home range near a trap. A considerable error in population estimates may be caused by heterogeneous trap response when census methods which assume uniform trap response are applied. From this study, it is apparent that the use of a shot sample to determine the marked-unmarked ratio in a rabbit population yields a more accurate estimation of the number present than does the use of mark-and-release trapping data alone.

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A PUNCH-CARD BIBLIOGRAPHIC FILE FOR VERTEBRATE ECOLOGISTS

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INTRODUCTION

Many individuals working in various scientific fields do not have ready access to libraries and need to maintain their own bibliographic files. Others prefer, in any event, to maintain their own personal card files to the literature. The notch-card technique, described here, has been developed to fit these needs. It is for personal use but may also be suitable for cooperative use by groups of scientists and by small libraries.

The process of developing a card file of literature references entails many difficulties. Essentially these difficulties are all included in three general categories—subject matter classification, cross referencing, and cost.

SUBJECT CLASSIFICATION. It is necessary to classify the many details of vertebrate ecology so that cards may be filed according to the scheme of classification. Otherwise, there would be no way of selecting from the file the information needed at any particular time on a particular subject. Unfortunately, there is no "natural" or objective classification. Any classification used must necessarily be artificial and subjective. Therefore, there can be no classification which is immediately suitable for all persons who may wish to use it. Yeager (1940) has published a subject-matter classification which he uses in filing cards for wildlife literature. But, as he points out (personal correspondence), he alone is able to use his own system satisfactorily. Cohen and Nagel (1934) have discussed this problem and conclude that "controversies as to what is the proper classification of the various sciences are interminable, since the various sciences may be classified in different ways, according to the objectives of such classification."

The card file system presented here attempts to allow for this dilemma of classification by suggesting the mechanics of classification while leaving it to the individual to do his own actual classifying. This will be discussed further after the file has been described.

CROSS REFERENCING. The problem of cross referencing applies not only to the

subject-matter classifications but also to authors, dates, and perhaps other attributes of a reference. With a plain card file, one may store cards according to one classification by the use of tab cards. Unfortunately many, perhaps most, references contain information which fits several different headings. Then the only way to file the reference under all of its contained headings is to make duplicate (often triplicate and quadruplicate) cards, each copy to be filed under different headings. The notch-card system provides multiple cross referencing with only one card per title.

COST. Because the notch-card system eliminates the need for duplicate cards, it may be less expensive than the ordinary card systems. On the other hand the notch cards cost more than plain cards, which may cancel the savings due to the use of fewer cards.

The cost of individual cards decreases as the number of cards purchased at one time increases. Some saving may be effected by group purchases. Since the codes set up by different individuals need not change the form of the card itself, such group purchases are possible. An idea of the economies to be effected is given by the following scale of prices for different numbers of cards.

Number of Cards	Approximate Cost per Thousand
1,000	$11.35
5,000	11.05
10,000	10.75
15,000	9.30

(Names of firms which sell notch-cards and equipment will be furnished upon request to the author.)

The cards should be printed with guide lines and code numbers opposite the appropriate holes, as in Figure 1. The cost of such printing can best be ascertained by soliciting bids from local printing establishments or the companies which manufacture the cards.

The only equipment needed by the individual to operate the notch-card system is a notching punch and sorting needle. The cost of these is approximately $3.75 for the punch and $3.00 for the needle.

THE PROPOSED NOTCH-CARD

The notch-card, which is proposed for a vertebrate ecology file, is shown in Figure 1. Its details and uses are described below. Most of the principles of the notch-card have already been described (Adams, 1950) and will not be repeated here.

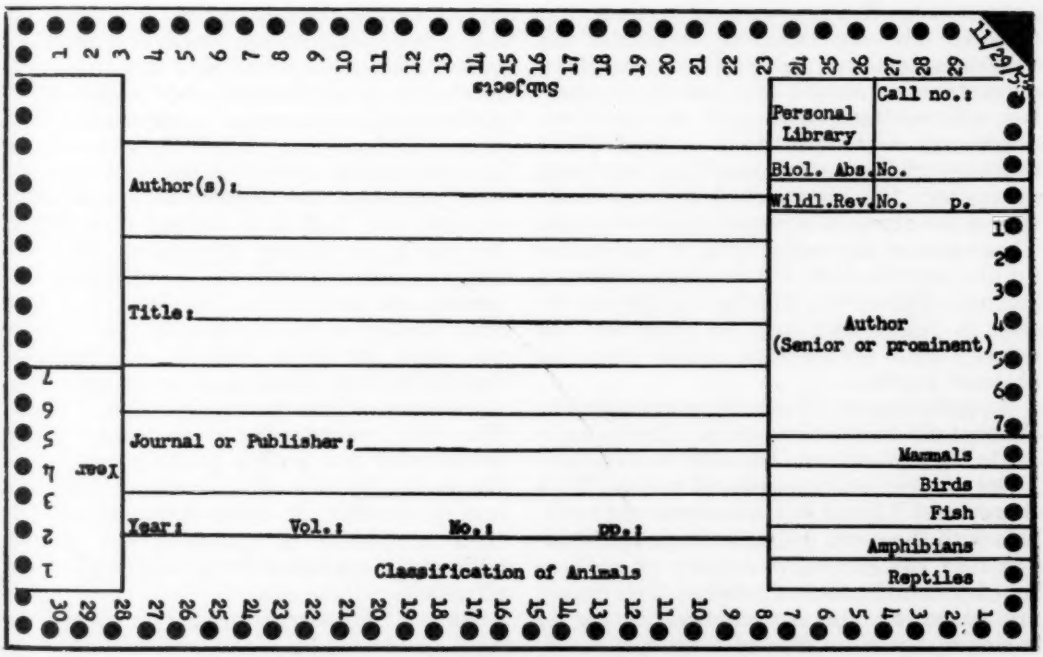

FIG. 1.—This notch-card design is described in detail in the text.

The card has a central space where the usual reference data (author, title, and journal) are entered. Around this central space and next to the border, holes are labelled to indicate uses for the different holes. These labels are blocked off by lines which help to match the labels to their respective holes. Starting at the upper right-hand corner of the card, the labels are here discussed in order working clockwise around the card.

LIBRARY INDEX. The first label is "Personal Library." It has a space for a call number and covers two holes. This furnishes an index to the owner's personal library. If holes are notched, it indicates that the reference is in the owner's library. If he has a call number system, it should be entered in the indicated space at the time the card is filed. Two holes are provided for the following purpose. Usually personal libraries are stored in different compartments—often with reprints in one place, books in another place, and journals may be in still a third place. The two holes may be notched in three ways —the top hole only, the bottom hole only, or both holes. These combinations may be used to indicate whether the reference is in the reprint file, the book case, or the journal files. Other uses may, of course, be substituted.

ABSTRACT REFERENCES. The next two holes are labeled "Biological Abstracts" and "Wildlife Reviews" and have space for references to the location of abstracts in these two abstracting journals. If the hole opposite one of these labels is unpunched, it indicates that the reference has not been abstracted. If it is punched then the location of the abstract is immediately available. These entries are easily made if one makes up his card file from entries in the abstract journals themselves. The back of the notch-card is blank and may be used for the owner's own abstract or copies from the abstract journals.

AUTHOR INDEX. The next seven holes are devoted to the author index. Provision is made for one author. The code used here is based on the binary system of coding. With this system 128 subject categories are available with the seven holes. Authors are classified into 128 groups, one group of authors for each combination of notches. The classes are based on the alphabetical listing of names in *American Men of Science*, (Cattell, 1949). This book was divided into 128 parts, each containing an equal number of pages. Then the first four letters of the first name in each part were used as the dividing point for each class. This method was used instead of a more mechanical means of dividing the alphabet because the distribution of names through the alphabet is not uniform. Using a list of actual names tends to give a more uniform distribution among the various classes.

A few entries of the author code sheet is presented here as an illustration of the method of classification. The holes notched are indicated by the crossed out 0's.

1 2 3 4 5 6 7		1 2 3 4 5 6 7	
o o o o o o o	Anonymous	ø ø o ø ø ø ø	Wiau - Will
ø o o o o o o	Aaaa - Albu	o o ø ø ø ø ø	Wilm - Wiss
o ø o o o o o	Albv - Amsd	ø o ø ø ø ø ø	Wist - Wool
ø ø o o o o o	Amse - Argu	o ø ø ø ø ø ø	Woom - Youn
o o ø o o o o	Argv - Babc	ø ø ø ø ø ø ø	Youo - Zzzz
			and various authors

etc.

Many different types of author codes have been developed, some simpler and some more complex than the one used here. The reader may wish to review the various methods of alphabetical coding in Casey and Perry (1951). This one was chosen because it is fairly simple and is best adapted for serial sorting so that all cards may be quickly placed in alphabetical order by authors. It has three shortcomings which can be eliminated with other systems. First, it can be used only for a "partial sort." That is, all authors within a coded classification will drop together when sorted. For example, all authors named Abbott, Adair, and Albright will fall when the deck is sorted for hole number one. And these will not be in alphabetical order among themselves. This requires a certain amount of hand sorting following the mechanical sorting. A second shortcoming of this system is that it does not allow for quick selective sorting. This feature was sacrificed in favor of the serial-sort feature which the binary system allows. The third shortcoming is that this system allows only one author to be notched into the card. Various other systems eliminate one or another of these shortcomings but their complexity of operation was deemed sufficiently undesirable to outweigh their advantages.

ANIMAL CLASSIFICATION. The rest of the right-hand side and the entire bottom of the card are devoted to an index to the ver-

tebrates. On the right side of the card five main classes of vertebrate animals are shown, each with its individual notching hole. They are used as a general index to the vertebrates. If a reference deals with a great variety of birds or fish, etc.—too many to index in the holes at the bottom of the card—then the appropriate general classes involved may be simply notched in this direct code on the side. Note that this is in part a duplication of the next code to be described and may therefore be omitted if it is desired to do so.

The holes across the bottom are numbered from one to thirty. These are used, in a coding method known as superimposition, to code all the vertebrates.

The superimposition method was not described in my earlier paper (Adams, 1950) so a rather detailed description of its principles and application is given here. For a more detailed description with mathematical analyses of its operation, the reader should see Casey and Perry (1951). According to this method, each item to be coded is given a set of randomly chosen code numbers ranging from 1 to 30 (or to as high as the code holes are numbered). In this case, each item of the entire classification of mammals and birds is given four code numbers from 1 to 30. (The same can be done for fish, amphibians, and reptiles by those who wish to do so.) Each Order, Family, Genus, and Species has a set of four code numbers which were drawn from a table of random numbers such as the table in Snedecor (1946), thus:

Mammalia	5	8	25	28	Mammals
Marsupialia	5	15	17	28	Marsupials
Didelphiidae	6	16	20	24	Opossums
Didelphis	7	8	16	30	
virginianus	11	14	16	21	Virginia opossum
marsupialis	5	8	21	23	Mexican opossum
Insectivora	5	15	24	30	Moles and Shrews
Talpidae	15	17	18	19	Moles
Condylura	1	11	14	30	
cristata	2	7	11	12	Starnose mole
Scalopus	9	22	26	28	
aquaticus	9	17	21	22	Eastern mole
Parascalops	1	3	12	21	
breweri	4	5	13	27	Hairytailed mole
Scapanus	1	7	15	20	
townsendi	4	11	12	24	Townsend mole

etc.

The nomenclature and classification follows Burt and Grossenheider (1952) for mammals and the AOU Check List (1931), with revisions as published in various issues of *The Auk*, for birds.

Having prepared a code such as this, the animals pertaining to a given reference may be indexed on the card simply by notching its four code numbers. The great advantage of this system lies in the fact that several species, genera, families, orders, and classes may be punched into the bank of 30 holes in a single card. It is unimportant that some of the notches of one entry will coincide with some of the notches of another entry. Thus, if *Parascalops* (1 3 12 21) and *Scapanus* (1 7 15 20) are both notched out, the hole numbered one will be included in both notchings. Nor does it matter that if several code sets are notched into a card their combination may accidentally conform with a code which is not intended to be notched. Thus, if *Condylura* (1 11 14 30) *cristata* (2 7 11 12), Insectivora (5 15 24 30) and Didelphiidae (6 16 20 24) were all notched into a single card, then a sort for *Scapanus* (1 7 15 20) would drop that card, even though *Scapanus* had not been intentionally included in the notching. These accidental sorts must be sorted out by hand after the mechanical sorting has been done. They are tolerated because they are inevitable in the method of superimposition, but if the system is properly designed the number of accidental sorts will be only a small percentage of the dropped cards and will entail no great difficulties in hand sorting.

YEAR. Starting up the left side of the card, the first bank of seven holes is used for indexing the year of publications. The code used here is the binary code like the one used for authors. Each notching combination is assigned a year. Thus,

o o o o o o o - 1900 and before
ø o o o o o o - 1901
o ø o o o o o - 1902
ø ø o o o o o - 1903
o o ø o o o o - 1904

etc.

There are sufficient code combinations to carry dates to the year 2026. The code for the year 1953 is ø ø ø o ø ø o.

The next 9 holes on the left side of the card have no index indicated. These may be used at once or at any future date for any index the owner may wish to introduce. This gives added flexibility for uses by different individuals and at different times. I use six of these holes for a geographic index using the binary code. The six holes give a

capacity of 64 geographic categories. I have used these for each of the 48 states and for other geographic categories covering the earth.

SUBJECT. The subject index includes the 29 holes across the top of the card. It is a superimposition code like the Classification of Animals at the bottom of the card.

The form to be used in this index is probably more subject to personal needs and prejudices than any of the others. Each individual will have his own idea of a proper subject outline. Whatever his outline or classification, it may be used with this coding system without alterations in the form of the card. He needs only to give each of his subject classifications a set of four randomly chosen numbers ranging from 1 to 29. (You may use the random numbers drawn for the animal classification, omitting those containing the number 30.)

Frequently a person's requirements in a subject classification change. In his research, for instance, he may complete one project and start another with a new set of interests. He may then wish to add new headings or break a general heading up into a group of more detailed sub-headings. Such changes are accomplished simply by giving the new headings and sub-headings additional random number sets and proceeding as before.

SUMMARY

A punch-card bibliographic file is described from the standpoint of subject classification, cross referencing and cost. The system permits multiple cross referencing with only one card per title. The described card provides for an index to the personal literature file, citation to abstracts, author index, index to the vertebrates, year of publication, and subject index. Nine holes are uncoded for individuals to use in special ways. A code using superimposition allows the individual to establish his own subject-matter classification and to alter it from time to time to suit changing requirements.

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TECHNIQUES FOR TAKING BLOOD SAMPLES FROM LIVING BIRDS

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Sooter (1954) presented a method of cardiac puncture used by his laboratory for bleeding nestling birds. We have been confronted with the same problem of adequate serial sampling of avian bloods in our studies of birds and their relationship to Japanese B encephalitis and have discarded the cardiac puncture as a laboratory or field method.

During the years 1946 through 1950, observations were made of avian relationships to western equine and St. Louis encephalitis in the southern San Joaquin Valley of California under the direction of Dr. W. C. Reeves. Our first interest was in possible vectors carrying both encephalitis virus and blood protozoa and to find out if birds commonly infected with encephalitis were also heavily parasitized with blood protozoa. The simplest technique was that of clipping the center toenail of a nestling or trapped adult just deep enough so that a few drops of blood oozed out, and making a blood smear on a glass slide at the time the bird was handled or banded. Subsequent handlings gave information on the duration of a protozoal infection.

When sufficient blood was needed to yield serum for serological tests for virus studies, trapped or nestling birds were taken to the laboratory. Here they were bled from the heart by inserting the hypodermic needle through the suprasternal passage. Size of the needle depended upon the size of the bird, ranging from 27 to 20 gauge. In most instances small species were involved, and the bird was bled out. However, with valuable birds or those to be bled more than once, quantities of 0.5 to 1.0 cc. only were taken. Because of the positions of the aorta, lung, heart, syrinx and other vital organs, it took considerable skill to strike the heart and not damage other tissues. In many instances birds so handled died even when small volumes of blood were removed. In several cases those that survived were kept in the aviary for periods up to a year. When they died, in each instance scar tissue was found upon the heart, which probably shortened the bird's life.

In studies involving chickens and larger birds the cardiac puncture was made from the same position of the needle as shown in Sooter's drawing. Individuals of domestic species were bled at regular intervals by this method and seemed to suffer no lethal heart damage.

During 1950 and 1951 nearly 3000 birds were collected in Japan for Japanese B encephalitis studies. In most cases these were bled by cardiac puncture through the suprasternal passage. As the study progressed and it became desirable to take more than one blood sample from small species, the ventral thoracic cardiac puncture was again tried. This proved too often fatal in the hands of unskilled laboratory technicians. After examining the hearts of nestlings so bled it was felt the effect of scar tissue and needle damage might produce detrimental results on the bird in sustained flight and activity of adult life.

Use of the brachial vein as a source of blood proved awkward and often difficult. Since the blood flows inward from the wing tip it is necessary to extend the wing and raise it, bleeding from the ventral surface. Often the bird's body is in the way of the technician's fingers or the syringe. The only damage to the bird by this method is a hematoma of a size related to the needle used and the operator's skill.

In 1952 a series of serological tests was begun on chicks one day to 14 days old and the jugular vein presented a good source of blood. A quick survey among wild birds revealed that jugular veins are asymmetrical, the right one being much larger than the left. This is sufficiently large for operation in even one- to two-day-old sparrows, and in species as large as the black-crowned night heron or egret even 20-gauge needles can be used on fledglings with no ill effects.

FIG. 1. Taking blood from the jugular vein of a nestling blue magpie, *Cyanopica cyanus*.

FIG. 2. Two persons take blood from the jugular vein of a nestling great egret, *Egretta alba*.

The use of the jugular vein is now the procedure of choice.

Our method has been refined until now it is a simple process which can be mastered by a new technician in a few tries, and his failures are not fatal to the bird. The size of the needle or syringe is dependent upon the size of the bird and the needs of the study. From species as large as a starling we can take 0.4 cc. of blood every day for a week or more, while from larger species the yield can be 3.0 cc. or more at weekly intervals. A small bird can be held on its back in the left hand with the first and second fingers braced against the skull and extending the neck. The neck is swabbed with alcohol which lays the feathers aside and exposes the jugular. Slight pressure at the base of the neck with the thumb distends the vein with blood, and the syringe can be operated by the right hand (Fig. 1). After the needle has been extracted, the wound is held under pressure by a finger for a moment or two, depending upon the species, until the bleeding stops. For larger species one operator holds the bird and presses on the vein while the other extends the neck and manipulates the syringe (Fig. 2).

Training our own men for this work we have bled more than 3000 birds in the past three years including species as small as the tree sparrow (*Passer montanus*) up to adult great egrets (*Egretta alba*) and our only losses have been when some untrained person held a bird and squeezed it too hard while it was being bled. In one instance a sick egret bled to death after the technician failed to hold the injury under pressure until the blood coagulated.

In all our field and laboratory work we wet our syringes with heparin before using them, thereby preventing coagulation in the needle or syringe. The consequent volume of plasma is greater than the volume of serum obtained from clotted blood and is equally satisfactory in serological tests.

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THE DETERMINATION OF AGE OF NESTLING AND SUB-ADULT GRAY SQUIRRELS IN WEST VIRGINIA[1]

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Conservation Commission of West Virginia

The inspection of den trees, boxes and leaf nests in order to ascertain the peak parturition period of the gray squirrel, *Sciurus carolinensis*, has been undertaken by almost every investigator studying this species. Due to the difficulty in finding litters, none has published any work that can be used as a basis for age determination.

The writer has found, however, the work of Monica Shorton (1951) in Great Britain to be outstanding. Table 1 is based on her work and the additional data on 68 nestling squirrels of varying ages collected during the present study. All data pertaining to nestling squirrels were collected on Seneca State Forest, located in the Allegheny Plateau Region of West Virginia. Data on the sub-adults (squirrels over 10 weeks old) were collected on Seneca and six other state forests and refuges located throughout the State. Fifty-one nestlings (19 litters) were checked once, nine (three litters) twice, six (two litters) four times and two (one litter) six times. The checks were made at intervals of one to three weeks. Repeated visits were made to all litter sites, but in the majority of cases the litters were not present the second time. Data were also collected from nestlings born in captivity. In these cases the mother usually devoured her young after they had been handled several times.

Notes were taken on the condition of the pelage, eyes, ears and teeth at each examination. Measurements of the hind foot, body and tail length were also taken and each squirrel was weighed. While the key was developed on the basis of the data obtained from the squirrels found in the spring and summer of 1953, it was applied again to the squirrels found during the spring of 1954. Some corrections and additions were made after the latter check. It was found that the key applied in the majority of cases, but occasionally one of the characteristics would not fall in the same age class as the others; however, in most instances, five of the seven criteria were valid. Spring litters in 1954 were larger than in 1953. It was found that one runt was present in the majority of cases where there were four squirrels in the litter. Data on these runts were not used in developing the aging key.

PELAGE: Squirrels are born naked. When the nestlings are two weeks old their dorsal surface is darkened by the emergence of hair. At three weeks this hair is about one millimeter long. At four weeks the silver hair on the tail is about two millimeters long. The ventral side of the tail is bare, and this portion of the tail does not become covered with hair until the nestling is six weeks old.

EYES: While Seton (1937) states that the eyes open when the squirrel is about 37 days old, this study has found that there is considerable variation among the litters and even within litters. The majority had milky or clear eyes by the fifth week; however, several had open and clear eyes by an estimated age of four and one-half weeks while others had only one eye open by the sixth week. Shorton (*op. cit.*) reported that two squirrels opened their eyes at the estimated age of twenty-four days while two more of a different litter were found to have their eyes open and clear when thirty-four days old.

EARS: The ears of gray squirrels generally open at three to four weeks of age. Brown and Yeager (1945) report that the ears of fox squirrels do not open until the sixth week. Allen (1943) reported that the ears of fox squirrels open in the third week, which is similar to the findings of the present study.

TEETH: The lower incisors of the gray squirrel nestlings were usually erupted at three weeks of age while the upper incisors did not show until the latter half of the fourth week. These findings are similar to those of Shorton (*op. cit.*) in Great Britain and Brown and Yeager (*op. cit.*) on fox squirrels in Illinois. A further study of the replacement of the temporary cheek teeth and the eruption and shape of the permanent cheek teeth would perhaps throw light on a

[1] A contribution of Pittman-Robertson Project 31-R.

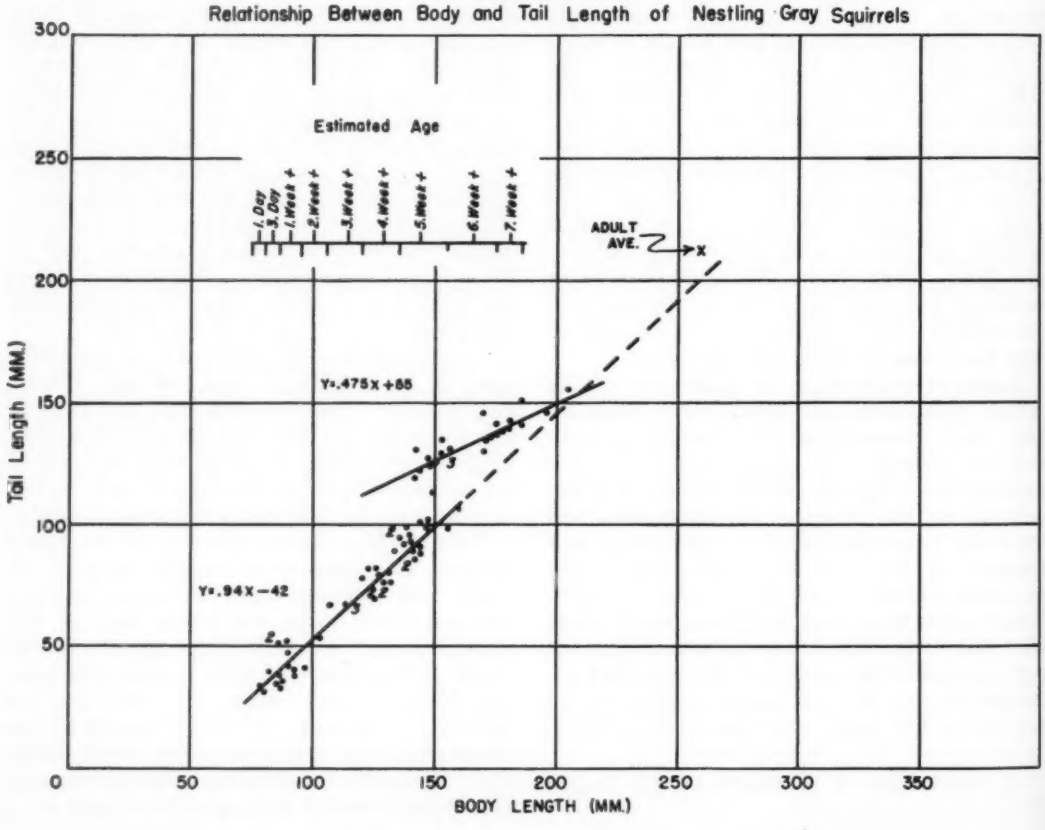
new method to separate adults from subadults during the hunting season. Shorton (*op. cit.*) states that the first cheek teeth are cast at thirty-one weeks of age.

HIND FOOT: Measurements of the hind foot were found to offer a good indication of age during the first three weeks. Considerable overlapping existed thereafter.

BODY AND TAIL LENGTH RELATIONSHIP: Body and total length measurements were taken from 68 specimens of various ages. The body lengths were then subtracted from the total lengths to obtain the tail lengths. The body and tail measurements were plotted and an examination of the figures indicated a relationship which was characterized by a definite inflexion that occurred at a body length of approximately 140 millimeters, or when the nestlings were a little over five weeks old (Figure 1). This inflexion was apparently due to a rapid increase in the tail growth. This increase in the growth of the tail continues with decreasing momentum until the body length is about 210 millimeters long or when the squirrel is between eight and nine weeks of age. At this point the two lines meet and presumably continue in their original relationship until the full adult growth is attained. Full adult growth is shown by the "X" in the upper right hand corner of Figure 1, where the extension of the original line about meets it. This "X" represents the average measurements of twenty-four adult gray squirrels.

BODY LENGTH AND WEIGHT RELATIONSHIP: During the first three weeks the body length and weight of a nestling gray squirrel apparently increases proportionately (Figure 2). During the fourth week, however, there apparently is an increase in body length while gain in weight lags. This continues through the first part of the fifth week, then the two again increase proportionately until the sixth week. During the sixth week growth in the body length is retarded while weight continues to increase. Presumably

FIGURE 1.
Relationship Between Body and Tail Length of Nestling Gray Squirrels



the nestling squirrel fills out during this period, for during the seventh week the body again lengthens and the two are again almost in proportion. At this stage, however, there is considerable variation.

AGING BY WEIGHT: Aging by weight in this paper is based on gray squirrels studied on Seneca State Forest where they attain an average adult weight of 555 grams. Several repeated weights of both captive and wild specimens found in the den boxes were obtained in this study and closely followed the weights given by Shorton (*op. cit.*). Table 1 gives the weight ranges of each age class as secured from the nestling gray squirrels. Overlap will at times occur after the nestlings reach an age of five or six weeks.

On the basis of further data gathered, it appears that when mass weight data of sub-adult squirrels are collected, weight can be used to determine the parturition period peaks, provided the squirrels weigh under 400 grams (Table 2). This table is particularly adaptable for use at checking stations on areas where controlled hunting is in force.

Due to the variance in weights in these age classes, overlapping does occur in individuals. It is believed, however, that when a large number of weights are obtained, the heavier squirrels are balanced by the light ones. In addition, a moving average may be applied to smooth out irregularities. While adult males apparently have a wider range of weights and also range heavier than adult females, sex ratios of the sub-adult squirrels by weight classes indicate that the heavier males do not outgrow the females until after they reach 450 grams. Weights of 4050 squirrels classified as adults and taken on the state forests throughout West Virginia indicated little difference in weight between sexes; the males averaged 523 grams and the females 518 grams (Uhlig, 1955). The 884 adults taken on Seneca State Forest averaged 559 grams for the males and 551 for the females.

FIGURE 2.

Relationship Between Weight and Body Length of Nestling Grey Squirrels

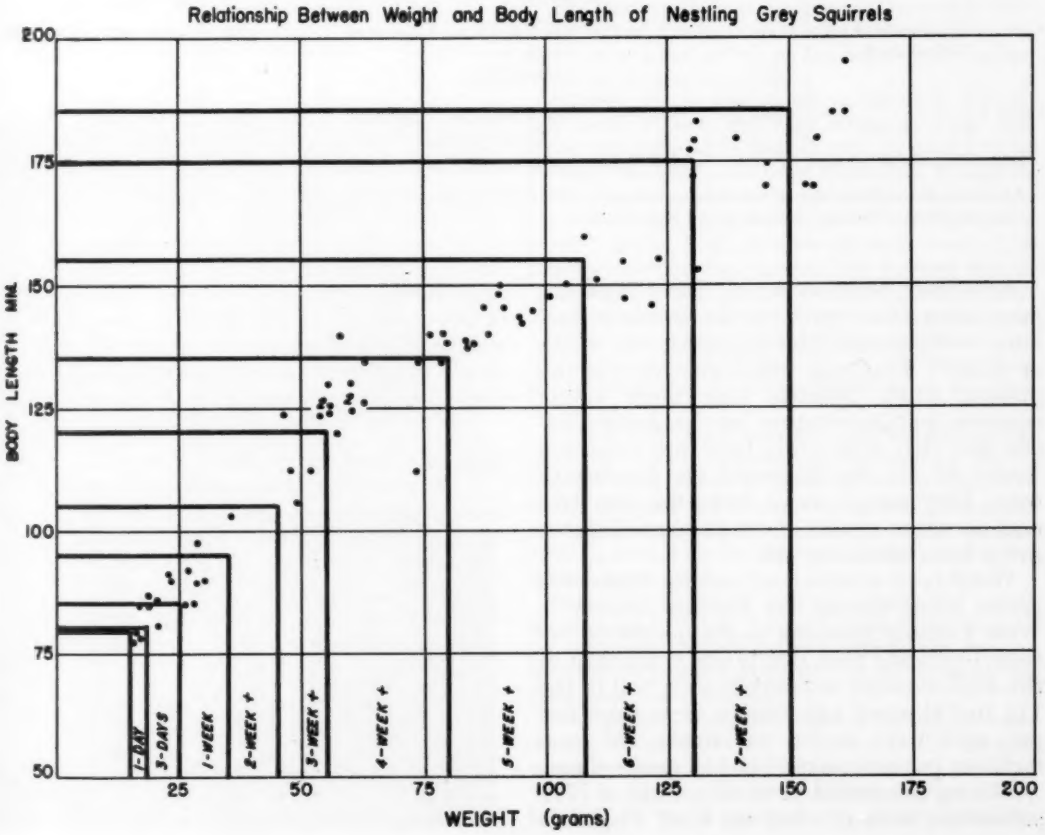


TABLE 1.—AGING CRITERIA OF NESTLING GRAY SQUIRRELS.* AVERAGE ADULT WEIGHT—555 GRAMS

Age	Pelage	Eyes	Ears	Teeth	Hind Foot mm.	Body Length mm.	Total Length mm.	Weight grams
1 day	Naked	Closed	Closed	None	13 – 14	78 – 80	109 – 119	15–18
3 days	Bristles on snout.	Closed	Closed	None	14 – 15	81 – 85	120 – 124	19–25
1 wk. +	Same	Closed	Closed	None	16 – 19	86 – 95	125 – 145	26–35
2 wks. +	Hair emerging on dorsal surface, body darkened.	Closed	Closed	None	20 – 25	96 – 105	146 – 162	36–45
3 wks. +	Hair 1 mm. long on dorsal surface.	Closed	Open during latter 1/2 of wk.	Lower incisors erupted or nearly so.	26 – 32	106 – 120	163 – 190	46–55
4 wks. +	Silvery hair on tail about 2 mm. long. Underside of tail bare. Body covered with hair.	Eye lids might be slightly open in corner during latter 1/2 of week.		L.I. 1–2 mm. long. Up. I. possibly erupted.	Not valid	121 – 135	191 – 225	56–80
5 wks. +	Tail covered with silvery hairs. A few hairs on underside of tail.	Eyes closed, milky or wide open and clear.		L.I. 2–5 mm. Up. I – erupted	Not valid	136 – 155	226 – 283 Tail begins accelerated growth.	81–108
6 wks. +	Underside of tail fully furred	Open		L.I. 4–6 mm. Up. I. – 1–2 mm.	Not valid	156 – 175	284 – 313	108–130
7 wks. +	.....	Open		L.I. 6–8 mm. Up.I.2–3 mm.	Not valid	175 – 185	314 – 328	131–150

* A slide rule for dating natural events as mating date, birth date, weaning period, etc. may be devised on the basis of this table in the manner of Kabat, Thompson and Kozlik (1950).

ACTIVITY: Shorton states that "Weaning may occur from seven weeks onwards, and may continue until the young are ten weeks or older." Trapping operations during the present study indicate that most young squirrels seldom venture on the ground below the den tree until they are over ten weeks old. By the thirteenth and fourteenth week they travel away from the den tree and are often caught in traps some distance away from the home site.

Weights of summer sub-adults under 400 grams taken during five hunting seasons in West Virginia (opening in the middle of October) indicate that nearly sixty per cent of the 4297 summer sub-adults shot, fell in the 11½ to 15½ week age classes. Less than five per cent were under ten weeks old, and eighteen per cent were 10 to 11½ weeks of age.

During the period 1949–53 a total of 7777 sub-adults were checked on West Virginia's state forests. Fifty-five per cent of these was of the summer litter while forty-five per cent was products of the spring litter. While this would indicate an equal amount of reproduction during the spring and summer, an

TABLE 2.—APPROXIMATE AGES OF JUVENILE* GRAY SQUIRRELS AS DETERMINED BY WEIGHT

Weight Classes Grams	Approximate Age Days
Nestlings:	
101 - 150	40 - 55
151 - 200	56 - 68
Sub-adults:	
201 - 250	69 - 80
251 - 300	81 - 94
301 - 350	95 - 108
351 - 400	109 - 125

* Nestling and Sub-adults.

analysis by individual forests and years shows that the spring litter produced the bulk of the sub-adult crop in only one out of the past five years. Combining the results of all the state forest, it appears that July is the most important period of squirrel production.

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OBITUARIES

REUBEN WILLIAM ESCHMEYER

1905—1955

Dr. Reuben William Eschmeyer, Executive Vice President of the Sport Fishing Institute, died suddenly of a heart attack at his home in Arlington, Virginia, on May 21, 1955.

"Rube", as he was known to his early friends, was born in New Knoxville, Ohio, in 1905, and spent his boyhood in the vicinity of nearby New Bremen. He graduated from Heidelberg College in 1927 and after a brief interlude of high school teaching entered the graduate school of the University of Michigan in 1930. Here his life work received its original direction and impetus. His doctoral studies were supported by one of the first fellowships provided by the Institute for Fisheries Research, a cooperative unit of the Michigan Department of Conservation and the University of Michigan then newly established under the direction of Dr. Carl L. Hubbs.

During this period with the Institute Eschmeyer made his first important contributions to fishery science: development of methods for lake improvement; recognition of overcrowding and consequent deterioration of lake fish populations; and development of techniques for the use of rotenone as a fish management tool.

Receiving his Ph.D. in 1937, Eschmeyer joined the Tennessee Valley Authority, ultimately becoming Assistant Chief of its Fish and Game Branch. In 1950 he joined the Sport Fishing Institute as Executive Vice President.

While still at Michigan, Rube developed the keen interest in interpretation of science to the layman which he performed so brilliantly during his later years. A devout disciple of the late, great, P. S. Lovejoy, he worked tirelessly to perfect the clear,

forceful style which came to be the hallmark of his writing and public speaking.

In his short life Dr. Eschmeyer combined several distinguished careers, any one of which would have seemed more than adequate to lesser men. His personal research, in addition to that already mentioned, included important contributions in the fields of fish populations, fish growth rate, and creel census. As a fishery administrator at TVA he was able to implement his findings in progressive management plans, notably in the curtailment of wasteful stocking practices and the relaxation of angling restrictions on warm water species, plans now widely followed elsewhere.

As a consultant to many agencies he worked to great effect in bringing about the abandonment of outmoded fish management practices and the adoption of technically sound programs. More important, he was highly influential in persuading administrators to build up—and heed the advice of—technical staffs, to insure continued progress in public service.

Conservation education was Rube's real love. Convinced that enlightened management of our renewable natural resources could never reach its full potential unless each citizen understood the problems involved and his own personal stake in them, he used every outlet for his facile pen to keep these matters in the public eye. By turns persuasive or accusing, but always informative and witty, his popular articles, children's books, Sport Fishing Institute *Bulletins*, and innumerable speeches reached, and we feel sure influenced, a wider section of the public than those of any other single worker of our time.

Rube is survived by his wife, Ruth Willey Eschmeyer, and three children, Barbara, William, and Jane. Despite the many demands for his services, he always found time for the family life which gave him his deepest satisfaction. He often remarked to friends that it was the desire to develop love and appreciation for nature in his children that started him on his series of widely acclaimed conservation books for children. And his keen sense of humor was appealed to when, long after his writing had become a model in the field, he prankishly wrote a theme for his daughter's college English class and it was returned to her, in due course, graded C–!

Rube's life was short. His achievements were great. He will be missed.—JUSTIN W. LEONARD

JOHN L. NEMES

1919—1955

John L. Nemes, District Game Manager for the Conservation Department in North-Central New York died March 30 after long illness, in Syracuse.

A key figure in the Department's Game Management program, Nemes will be greatly missed by his fellow workers and by the thousands of sportsmen who learned to love and respect him for his often colorful but always sincere and constructive efforts on their behalf. An enthusiastic hunter and fisherman, Nemes combined a sportsman's "know-how" with thorough training in the biological sciences toward real accomplishment in conservation throughout his district in north-central New York.

Nemes first joined the Conservation Department in 1946 and, following a number of special assignments, was appointed District Game Manager for the North-Central District in 1949. He was a graduate of Cornell University and a veteran of World War II during which he served as a first lieutenant in the Air Corps.—PAUL DALKE

HALLOCK JAY HOSFORD

1929—1955

"Jay" Hosford was born April 12, 1929 in Chicago, Illinois. He died of chronic nephritis on February 7, 1955 in Wilmington, Delaware. He was single, and the only son of Mr. and Mrs. H. C. Hosford, 1504 West 14th Street, Wilmington.

From his earliest boyhood days Jay had a fondness for the out-of-doors and soon developed a keen interest in the field of wildlife management. He attended Roosevelt High School, East Chicago, Indiana, and graduated in 1947. His undergraduate college training was completed at Purdue University, Lafayette, Indiana, in August 1951, when he was granted the degree Bachelor of Science in Agriculture. Jay distinguished himself at Purdue by the high scholastic level of his work and the strong possibilities he showed of furthering the interests of wildlife conservation. He was employed by the Indiana Lake and Stream Survey during the summer of 1947 and by the Indiana Department of Conservation during the springs of 1950 and 1951.

It was during his last year at Purdue that Jay first noticed his nephritic condition. Undaunted by prospects of what was to come in the future, Jay applied for, and was accepted as, a graduate assistant in wildlife at the University of Wisconsin, Madison, beginning with the fall semester, 1951.

His illness caused him to withdraw in November of that year while he underwent treatment for his serious kidney disorder.

Although Jay partially recuperated by resting during the spring and summer of 1952, he was advised by various doctors to go to a warmer climate because of his health. Consequently he applied for a graduate assistantship in the School of Forestry, University of Florida, Gainesville. When he was accepted, he commenced training toward his master's degree in wildlife management. His graduate work was concerned with the food habits of the Florida duck, but at the same time he collected much pertinent information on the life history and ecology of this species. He planned to use this information later as part of his doctoral training in the Department of Biology. Unfortunately, however, Jay passed away before he could complete his thesis work or his final oral examination for the master's degree.

While at the University of Florida Jay took an active interest in the Forestry Club, joined Xi Sigma Pi and became its Forester, and accepted membership in Phi Sigma Biological Society. With the passing of Jay Hosford the field of wildlife conservation lost a potential leader of the highest quality. He will long be remembered as an industrious, capable, and congenial worker by all who were associated with him.—STEPHEN L. BECKWITH

WILLIAM R. BERGESON

1909—1955

William R. Bergeson, Bergy to most of us, joined Montana's Fish and Game Department (Wildlife Restoration Division) in upland game bird research work in July of 1941. He had obtained his wildlife training at the Montana State University. In 1943, he was given an assignment to study in detail the relationship of the ringnecked pheasant to agriculture in Montana. This was a very controversial and important issue at that time. His excellent field work was the basis for a publication on the subject by joint authorship with Robert W. Hiatt. This information has been very useful in working out many of the plans for pheasant management in the State.

Following this intensive work, Bergy was transferred to the Helena headquarters. There he aided in building up and supervising a statewide upland game bird program.

Among his many interests was the possibility of introducing the chukar partridge into the State. He studied in detail the range in neighboring states as well as potential habitat in Montana. This work resulted in several subsequent introductions. Also, with a keen eye for future game bird possibilities, he carried out much of the spade work which resulted in a recent introduction of the Merriam turkey.

Bergy loved the out-of-doors. I think that is why he chose the wildlife field for his life work. This interest was shared by his wife and little daughter. Much of their spare time was spent at their summer cabin in the Birch Creek Canyon near Dillon.

Bill's untimely death on June 4, 1955, just when he was stepping into a challenging new job as a key member of the Department's newly organized district wildlife team, leaves Montana with a gap that will be hard to fill. He set an enviable mark in his profession. I think, however, that Bergy will be remembered most though for his warm friendliness and keen sense of humor. He was the kind of person with whom people like to work. I know that the deep sense of loss which we feel in Montana is shared by his many friends throughout the states.—ROBERT F. COONEY

RICHARD C. MARZOLF

1926—1955

Richard C. Marzolf drowned in a pond located on the Conservation Commission's August A. Busch Memorial Wildlife Area near St. Louis on July 8, 1955. At the time of his death, Mr. Marzolf was engaged in his research on channel catfish and was using an aqualung diving device.

He was born in Beloit, Kansas, August 15, 1926 and attended school in Glen Elder, Kansas. After serving in the U. S. Navy near the close of World War II, he enrolled at Kansas State College where he spent two years. Then he transferred to the University of Missouri. Here he received the Bachelor of Science degree in agriculture in 1950 and the Master's degree in field zoology in 1952 He joined the fishery biology staff of the Conservation Commission in March, 1952.

Dick was a member of the Wildlife Society, the American Fisheries Society and Gamma Sigma

Delta honorary agriculture fraternity. He published a paper on his work with channel catfish entitled, *Use of Pectoral Spines and Vertebrae for Determining Age and Rate of Growth of the Channel Catfish*, Jour. Wildl. Mgt., **19**: 243–249. He was also co-author with Arthur Witt, Jr. of a paper entitled, *Spawning and Behavior of the Longear Sunfish, Lepomis megalotis megalotis*, Copeia, 1954, **3**: 188–190. Other work which he did included an unpublished study of the value of rearing and stocking largemouth bass and a preliminary study on gigging in Ozark streams

He is survived by his wife and four children.

Dick Marzolf's untimely death is a stunning loss to his family, his friends and to the Conservation Commission. His associates were always impressed by his friendliness and sincerity and he commanded both affection and respect among them. Dick was a hard worker. He was loyal, and dependable and outstanding for his capability. He had the ability to think clearly and expressed himself accordingly. He thought nothing of working far beyond the call of duty. In fact, he died using equipment which he was not assigned to use but which would further the value of his work.—PAUL G. BARNICKOL

REVIEWS

Prairie Ducks. A Study of their Behavior, Ecology and Management. By Lyle K. Sowls. The Stackpole Company, Harrisburg, Pa. 193 pages. 1955. $4.75.

"Prairie Ducks" follows logically an earlier volume, "The Canvasback on a Prairie Marsh" by Hochbaum (1944) as a contribution from the Delta Waterfowl Research Station, operated by the North American Wildlife Foundation and The Wildlife Management Institute.

Despite the fact that management is the ultimate objective behind "Prairie Ducks," Sowls does not attempt to write a prescription for all the ills of waterfowl. Instead he sets forth facts revealed by work done at the Delta Station largely during the period 1946–1950, and from these he draws reasonable deductions. Throughout, the volume conveys the logical impression that, were similar data collected in adequate amount, the answers to many problems of waterfowl management would become self-evident.

The approach is through an intensive and intimate study of the individual duck carried out to the limit of the time and facilities available. The species involved were mallards, pintails, shovellers, gadwalls, and blue-winged teal. Through banding and color-marking, particularly of the hens, the seasonal history of the bird's "homing" to nesting grounds and the nature and extent of renesting were disclosed. Information on the land-water pattern and cover requirements, the influence of spring weather on the breeding, and the varied movements of the birds on their breeding grounds were other products of the study.

The return of the female to the same nesting meadow, sometimes for several successive years, focusses attention again on the mysterious ability of migratory birds to "home" precisely after a winter's sojourn at some point a thousand or more miles away. In this respect Sowls' volume is an enlightening companion to Matthews' recently published contribution on "Bird Navigation" (Cambridge University Press, 1955). The degree of migrational "homing" to a nesting area revealed by pintails, gadwalls and shovellers lent supporting evidence to the Hochbaum theory that local populations may be annihilated if they are hunted too heavily at or near their breeding site. Similar data regarding mallards and blue-winged teal were less convincing. At least as revealed at Delta, Sowls comments that "a low kill of pintails at Delta coincides with a high return of pintails a second year; and a high kill of mallards at Delta coincides with a low return of mallards a second year," (page 32). At Delta the "homing" data also confirm the conclusion, generally entertained, that the 1-year-old birds are the ones which pioneer to new areas even though a portion of the first-year breeders may return to their natal nesting area.

On the subject of renesting, that important but little understood aspect of waterfowl reproduction, Sowls' study of the individual bird has made a distinct contribution though much similar work remains before final deductions are possible. The significance of renesting in the survival of waterfowl is conveyed in his summarizing statement that "in some areas during some years it (renesting) may account for nearly the entire production."

As frequently happens, portions of an extensive treatise have appeared in serial literature previously. This happened with Sowls' discussion of the role of the Franklin ground squirrel as a duck-nest predator. His earlier contribution (Jour. Mammalogy, **29**: 113–137) covers this subject in greater detail and his more recent experiences confirm his belief that in the Delta area this rodent exerts a variable and at times an important effect on the meadow-nesting duck. As for the crow, Sowls, in common with Good in Ohio and Black in Illinois feels that the non-breeding juveniles are more destructive to duck nests than the breeding birds due to the fact that they commonly seek food in the nesting areas. This aspect of crow-duck relationships was not fully appreciated at the time of the reviewer's earlier work in Canada. Yet it seems odd that this one-brooded bird, subjected to unrestricted shooting and even bombing, maintains its numbers

despite the fact that it does not breed until the second year after hatching, and may not average over three young placed on the wing! Sowls, along with others, concludes that the role of predation in waterfowl production seems less significant than it did formerly and the factor most important in this connection is the ability and normal performance of ducks to renest when the first attempt fails.

Whereas the land-water pattern revealed by Sowls to be most attractive to waterfowl is something that lends itself to long-range management, another element, the weather, is something about which we can only talk, and then, if conditions have been adverse, hunting regulations can provide the only compensating influence.

The reviewer, having engaged in earlier studies of waterfowl ecology, recognizes gratifyingly, the progress that has been made in the last decade in the techniques of waterfowl appraisal. Dominant has been the banding, color-marking and day-by-day observations on individual birds. This is a long and tedious process, often with no immediate returns, but, in the end, there is an aggregation of facts that defy refutation.

The chapter-heading sketches by Hochbaum add much to the attractiveness of the volume. To one who has visited the Delta Station these illustrations, without titles, bring back vivid memories. A reproduction, in color of pintails by Peter Scott serves as a frontispiece and also as an embellishment of an attractive dust cover.

Concisely stated summaries at the end of each chapter are an aid to those who are searching quickly for pertinent information. The volume will be of help not only to those who are attempting to apply in management the salient facts of waterfowl ecology but, even more so, to the future research worker who may use the techniques developed in perfecting even more accurate methods of appraising waterfowl ecology and management. The volume is well printed and there is a minimum of errors and overlooked references.—E. R. KALMBACH.

The Natural Regulation of Animal Numbers. By David Lack. 1954. Oxford University Press, London EC 4. 343 pages. $5.60.

The Distribution and Abundance of Animals. By H. G. Andrewartha and L. C. Birch. 1954. The University of Chicago Press, Chicago 37. 782 pages. $15.00.

Two of the many diverse backgrounds of present day ecological work are exemplified by these two books. Treating similar subjects, the one has its inspiration in scientific field ornithology, which is carried out, one feels, under the critical scrutiny of an army of interested bird-watchers. The other conjures up a picture of hard-pressed economic entomologists who are asked to prevent insect plagues, or at least to predict their onset, and whose continuing prayer is for more successful agents of "biological control." Both books make considerable effort to consider work done on organisms outside their authors' specialties, Lack's treatment of other vertebrates being particularly commendable. However their principal value will be the reviews of facts and viewpoints prevailing in ecological ornithology and entomology, respectively.

Lack's book systematically reviews available quantitative information concerning all aspects of life history which bear on abundance: clutch size and litter size; mortality of eggs and young; adult mortality and population age and sex structure; food, disease and predation as possible controlling factors; effects of climate; cycles, irruptions, migration and dispersion. Surprisingly perhaps, general patterns do emerge from this review, and even some broad differences between different kinds of animals—all of which are succinctly summarized in the short concluding chapter. For example, known geographical variations in size of clutch and frequency of nesting among birds prove to be such that in each part of the range the number of young actually reared is the maximum possible in that region. This maximization of reproductive rate determines the high adult mortality rate—and not vice versa—since mortality rate is immediately lowered whenever, in exceptional circumstances, a population becomes sparse. As for causes of the mortality which limits population size, "food shortage appears to be the chief natural factor limiting the numbers of many birds, of various carnivorous and herbivorous mammals, of many larger marine fish, and of certain predatory insects. Predation seems the main factor in various gallinaceous birds, in North American deer (before their predators were destroyed by man), and in plant-eating insects. . . . Disease is of major importance at least in the red grouse, in man, and in an experimental population of flour beetles." But Lack is quick to add that this summary is an oversimplification, and points to interactions of malnutrition, disease and predators, and to the frequent difficulty of ascribing death to one cause or the other.

Andrewartha and Birch's book is differently arranged and covers a somewhat wider field. The introduction is devoted mainly to a justification of the individual-species approach: communities, as such, are not considered in either of the books under review. Part II treats "Physiological Aspects of Ecology," under which appear such topics as rate of increase, mortality and age structure, a long chapter on diapause in insects, and one on various aspects of dispersal. Part III is an "Analysis of Environment," divided into temperature, light, other animals of the same kind, other organisms of different kinds, food, and "a place in which to live." It is of course the reactions of animals to these factors that are treated, not the environment for its own sake. Part IV deals specifically with examples of natural populations whose variations in abundance, the authors feel, have been analyzed in sufficient

detail to assess the relative importance of different environmental factors in their regulation. Poorly-read vertebrate ecologists like the reviewer will appreciate the fairly detailed resumé of work done on a south Australian locust, a cutworm of the Rocky Mountain foothill region, the spruce budworm in eastern Canada, a blueberry fly in Maine, midges and worms in filter beds, sheep ticks in north England, a *Thrips* in an Adelaide rose garden, and others. Errington's work on bobwhite is the only vertebrate study which qualifies for special mention. A part of the extensive literature on periodicity of warm-blooded animals is reviewed, and is then dismissed with the admonition that what is obviously needed is more detailed information on the reactions of these creatures to their environment—a feeling which Lack shares. The final division of the book, on the "Genetic Aspects of Ecology," bears little obvious relation to what goes before.

If there is one thing more than another which relates Lack's book to Andrewartha and Birch's, it is the matter of "density-dependent factors." This notogean controversy shows some signs of overrunning the northern hemisphere in the same way that the prickly-pear cactus once spread across Australia. To introduce a *Cactoblastis* at this stage would spoil the fun, but a matter of definition should be cleared up. "Density-dependence" can be viewed either from the standpoint of the regulating agent or that of the animal regulated. To the reviewer, a density-dependent cause of mortality (more precisely, a *compensatory* cause) is one which kills a larger fraction of the regulated population as the latter increases in abundance over some part, but not necessarily the whole, of the spectrum of abundances that occur in nature. It is immaterial whether or not the agent in question is itself affected by the abundance or scarcity of the regulated organism. The control agent may in fact be such a thing as rainfall, which (let us say) kills a larger percentage of nestling martins when some birds must nest in poorly-protected situations because population is large. Andrewartha and Birch would subscribe to this definition, I believe, since on pages 18 and 19 they decide "that 'density-independent factors' do not exist," and "we do not know of any experimental or observational evidence which would indicate that any component of the environment characteristically destroys a constant proportion of the population, irrespective of its density." These statements may make the compensatory aspect of mortality seem more pervasive than it actually is, yet it is truly difficult to name any cause of death whose effectiveness is likely to be uniform over *all* possible densities of the organism affected.

Why, then, do Andrewartha and Birch repeatedly reach the conclusion, elsewhere in their book, that it is density-*dependent* factors which do not exist? For example, in summarizing their work on the *Thrips*, they note that "not only did we fail to find a 'density-dependent factor,' but we also showed that there was no room for one." The answer seems to be that they ascribe to Nicholson, H. S. Smith, Elton, Varley and others a narrower definition of density-dependence, one that restricts the term to mortality agents which can themselves change in abundance or in character as the density of the controlled animal changes—above all, biological agents. If I understand them rightly, it is only this particular kind of density-dependent factor which Andrewartha and Birch consider to be lacking in most of the animal populations they have examined. Actually, I cannot find that the four authors mentioned have ever subscribed to so restricted a definition; in fact Smith has specifically disclaimed it in a passage which Andrewartha and Birch quote ("under certain conditions it [climate] is capable of acting as a density-dependent factor"). Some of the others do focus attention on preceding rather than proximate causes of mortality, so that the extra deaths among the young martins above would "really" be due to the competitive situation in a dense population; but they would scarcely wish to deny that the mortality caused by the rain was density-dependent from the birds' point of view. And whatever the terminology, the same reaction of controlled to controller is being described.

What is true, of course, is that Nicholson *et al.* (and Lack is to be included here) are of the opinion that biological effects, especially malnutrition and the activity of parasites, predators and diseases, are the ones *usually* involved in control mechanisms. Andrewartha and Birch, by contrast, believe that these are no more important, or are less important, on present evidence, than are various aspects of the weather. The argument thus becomes a quantitative one, to be settled by more studies of vital statistics of populations in their natural environments, assisted, possibly, by a more critical consideration of studies already available. But concerning the reality of the compensatory principle involved in the regulation of animal numbers, the two schools are apparently in complete agreement.

Any author's facts are more to be trusted when they concern things of which he has first-hand knowledge, and these two books illustrate the point as well as any other. For example, Lack says (p. 251) that harp seals have their pups in Belle Isle Strait: actually this normally happens away from the Strait—either in the Gulf of St. Lawrence or off the northeast coast of Newfoundland and southern Labrador. Similarly, Andrewartha and Birch (p. 642) put "the number of salmon in the Fraser River" between the extremes of 15,000 in 1907 and 240,000 in 1913, figures which are about a hundredth of the catch of one species in those years. Experience shows that similar mistakes are inevitable whenever an author roams in territory outside his customary area of discovery. Since we wish to encourage these excursions, not discourage them, perhaps a work of synthesis should be awarded marks in proportion to the number of errors it contains! Even if these are rarely of any major consequence, nevertheless

readers who will call an author's attention to lapses constitute a valuable class of public benefactors: it is in this way that second editions become more authoritative. Both of these books are of sufficient importance for readers to take this trouble.—W. E. RICKER.

The Passenger Pigeon: Its Natural History and Extinction. By A. W. Schorger. The University of Wisconsin Press, 811 State Street, Madison, Wisconsin. 1955. xiii+424 pp. illus. $7.50.

From the State of Wisconsin has come another outstanding contribution to the memory of a species that faded before the advance of American civilization. Throughout the volume runs a constant background refrain parallel to the expression of Aldo Leopold in his Sand County Almanac (p. 108), "We have erected a monument to commemorate the funeral of a species."

Would a knowledge of basic wildlife ecology and management have exercised any significant influence on the fate of the passenger pigeon? Given another species of similar abundance and comparable habits in this day, would its history be written differently a hundred years hence? Just why did the passenger pigeon pass completely from the scene?

It may be in order to refer to the currently precarious status of the white-winged dove and the band-tailed pigeon for partial replies to the foregoing questions. Too, the answers may come in a matter of just a few years. Joint responsibility for the future of these two species rests with three groups, as did the fate of the passenger pigeon; namely, landowners and operators, State and Federal wildlife agencies, and the hunting public.

The author, in his Preface, states that he devoted the spare time of a score of years to interviews, correspondence and search of literature as a basis of information for his book. The results are a credit to the extent and thoroughness of such spare time effort. His careful selection of pertinent references included, as well as his conclusions, give ample evidence of having been tempered and seasoned by time.

THE PASSENGER PIGEON brings together a compilation of excerpts from the writings and oral accounts of many persons, ranging over a time period of four hundred years. Possibly the earliest quotation is from Cartier, dated July 1, 1534, and based on an observation made at Cape Orleans (Kildare), Prince Edward Island. Chronologically, the latest might be designated as the message on a bronze tablet in Wyalusing State Park, Wisconsin, dated May 11, 1947, "Dedicated to the last Wisconsin passenger pigeon shot at Babcock, September 1899. This species became extinct through the avarice and thoughtlessness of man." Intervening years brought a prodigious number of accounts from many people and places.

The author's task was to read, evaluate, organize and interpret such of the written material as appeared worthy of inclusion in his book. Interest in the volume should be wide; it has a variety and richness of information and thinking beyond the limits of any single group or field. There is history for the historians, ornithology for the ornithologists, basic thinking for the conservationists, and enough philosophy to carry its own way with others.

A principal theme of passenger pigeon accounts related to their incredible numbers. Few observers made any effort to conduct systematic counts of birds in flights; the best they could do was to indicate the approximate width of flights, and the time required for them to pass a given point. One opinion relative to pigeon numbers was prefaced with the remark that "It would be hard to make any estimate of their numbers that people would believe at this late date." There also were references to fears and superstitions aroused by the great hosts of pigeons. The author's conclusion on the point was to the effect that "It is an insuperable problem to determine the total population of the passenger pigeon at any one time."

Under chapters covering behavioral characteristics, food, movements, roosting and nesting, there appear clues to the vulnerability of the passenger pigeon. Its powerfully colonial habits were sufficient to offset temporary wariness on the part of either individuals or flocks. Nesting masses spread out over distances up to twenty miles in length, and contained numbers beyond imagination. Even in days of relatively sparse human population, such masses could not escape detection and persecution.

Chapters on utilization and methods of capture logically are followed by one designated as "Decrease and Extinction." Mass trapping, barrage types of shooting, clubbing by night, and every other conceivable means of capture or slaughter had a part in the decimation of what had so commonly been referred to as an unlimited and inexhaustible population. Captured birds were sold alive, killed and dressed for immediate sale, or fed and fattened for subsequent disposal. Many went to market in barrels containing 25 to 40 dozens each. There can be little wonder that decrease and extinction followed after a few decades of so intensive persecution. Even so, the author pointed out that "the end came quite gradually and not with catastrophic suddenness as is popularly believed."

Just why did the passenger pigeon become extinct? Reasons for its extinction were both numerous and varied. Among those cited were drowning en masse in the Gulf of Mexico or the Atlantic Ocean, migration to Chile or Peru, burning in forest fires, cutting of forests, forced nesting too far northward and subsequent loss of squabs, disease, and exhaustion of the germ plasm. Efforts to enact protective laws came too late, obviously, even to defer the bird's extirpation. Even so, Michigan prescribed a three-month open season for the species after it was gone. The author's conclusion is that "the passenger

pigeon became extinct through such constant persecution that it was unable to raise sufficient young to perpetuate the race." He also admitted impossibility of determining the species' threshold of survival.

Subsequent chapters cover description, anatomy and physiology, nomenclature, distribution, migration, late records, and evaluation of illustrations. While these present a wealth of information they seem somewhat anticlimactic; in a sense rather like raking through cold ashes after a fire has long been dead. It is in these chapters, however, that the professional ornithologist will find much detail of interest.

We can readily agree with the author that "It is unfortunate and most regrettable that no competent ornithologist attempted to make a comprehensive study of the nesting and other phases of the life history of the passenger pigeon while it existed in large numbers." Lacking the background of any such study, and without any remaining live birds as subjects, he has done the next best thing. We now can trace the story of a lost thing within the space of a few hours, which few, if any, of us would otherwise ever had an opportunity to do.—W. C. GLAZENER.

On the Food Habits of the Diving Ducks in Denmark. By F. Jensenius Madsen. Reprinted from the "Danish Review of Game Biology," Vol. 2, Part 3, pp. 157–266. Universitetets Zoologiske Museum, København, Copenhagen 1954.

This comprehensive food habits study is based on an analysis of the stomach contents, including both gizzard and gullet, of 2307 birds collected in Denmark and her coastal waters, mainly in the years 1940–43. The eight common diving species: the common eider, common scoter, velvet scoter, old squaw or longtailed duck, golden-eye, tufted duck, scaup and pochard are separately treated. It will be remembered that these are Europe's counterparts of our American divers. The eider, old squaw, golden-eye and scaup are the same as our American species, or only subspecifically different. In their relationships—taxonomically, habits, habitat, requirements and food habit preferences—all eight are very close to our American counterparts. Consequently, this food habits study is of particular interest and value to American workers.

This is the first detailed investigation of the food habits of the diving ducks in Denmark, and the most detailed European study yet made. The author appropriately has made a careful review of all previous studies, conducted both in Europe and America, of these and closely allied species of birds. His work is made the more interesting and valuable because of his careful comparisons of his results with the facts and conclusions of others. In general he gives confirmation to the studies by Cottam (1939. Food Habits of N. Amer. Diving Ducks. U.S.D.A. Tech. Bull. 643.) of the food habits of American divers.

The author is to be congratulated for his continued effort to interpret the food habits with the peculiar ecological requirements of the birds' normal feeding habitat. This study emphasizes how each species of diving duck occupies a distinctive ecological niche, which, though it may overlap with another diving duck, is different in the main and in that the various species, therefore, compete for food to a much smaller degree than might have been expected. The paper also shows the great adaptability of most diving ducks in adjusting to their environment and food availability.

The food habits are discussed and summarized in the different types of environments in which the birds were taken. For example, with the golden-eye, the foods are considered in the salt-water localities of the coastal ocean, the brackish water of the Sounds and Baltic, in the fjords and in fresh-water habitats. Apart from the pochard, the eight species treated have a northern or Arctic distribution. In Denmark they occur mainly as winter visitors, or spring and fall migrants. Only the pochard, the eider, and, to a lesser extent, the tufted duck occur sparingly as nesters in Denmark. The pochard and tufted duck are primarily fresh-water inhabitants. The others are largely marine birds, and most stay well out to sea. Because most of these species are scarce in Denmark in summer, this account, of necessity, is restricted almost entirely to the winter and migratory seasons. I glean the impression that because of differences of coastal topography, their scaup, golden-eye, and old squaws are somewhat more marine in habitat preferences than are these birds in America. Perhaps our more open coastal brackish bays and broad river estuaries are more attractive to these birds on this continent.

In treatment of food items Dr. Madsen has perhaps given a clearer picture of size of items consumed than has any previous worker. His treatment is very detailed and scholarly. It is a good contribution and will last as a permanent authoritative reference and standard work of the winter foods of most of Europe's diving ducks.

On only one major point can this writer take exception to Dr. Madsen's approach or conclusion. As is generally common on the continent of Europe, he has followed the numerical system of laboratory analysis, and states that he has followed this because of its greater accuracy and convenience. Our experience has been quite contrary to this if one uses proper equipment and facilities of measuring stomach contents. In America we have almost invariably given the volumetric percentages of items consumed, along with details of numbers of items of each food species consumed. I believe, therefore, our method has all the advantages of the European system, and some advantages besides. It helps the reader, who is not familiar with all the items listed,

to interpret the significance of any number of minute items as against one or a few large specimens of other items consumed.

Regardless of this difference of procedure and concept, this is an excellent contribution of great merit. Fortunately for Americans, this voluminous bulletin is presented in English, and is well written. The bulletin contains a good summary, and an appendix giving contents of typically well filled stomachs.—CLARENCE COTTAM.

RECENT PUBLICATIONS

Fish for More Fishermen. Michigan Department of Conservation, Lansing. 1955. (undated). 48 pp. Fine popular account, generously illustrated, of Michigan's fish management program.

Graduate Theses 1944–1954. Compiled by Genevieve L. Reidy. State University of New York, College of Forestry at Syracuse. 1955. 116 pp.

Brief abstracts of 150 graduate theses presented at the N. Y. State College of Forestry. Those on wildlife subjects total 25.

An Introduction to Ornithology. By George J. Wallace. Macmillan Company, New York. 1955. 443 pp. $8.00.

A general text in ornithology which contains several chapters of particular interest to wildlife researchers, e.g. on food habits and economic relations, conservation and management, and ornithological methods.

The Waterfowl of the World, Vol. 1 (Swans, geese, etc.). By Jean Delacour. Country Life, Ltd., London. 1954. 284 pp. 5 guineas (ca. $15.00).

The first volume of a projected 3-volume sumptuous work illustrated with color paintings by Peter Scott. Nomenclature follows the system proposed with Mayr in 1945 which is now widely adopted. This volume covers over 80 species and subspecies, so the individual accounts of distribution, general habits, etc., are brief. The 16 color plates illustrate all species and include 3 plates of the downy young.

Hunting Whitetails. By Frank C. Edminister. William Morrow & Co., New York. 1954. 192 pp. $3.75.

Primarily about hunting. This well written book had excellent sections on deer management and biology. In addition to the expected descriptions of hunting equipment and methods there are well written sections on the recreational value and the ethics of deer hunting.

Danish Review of Game Biology, Volume II, and III, Part 1. 1952–1954. Published by J. H. Schultz Ltd., Copenhagen for the Game Foundation's Wildlife Investigations (Zoological Museum, Copenhagen) and the Game Research Station (Kalø pr. Ronde, Denmark).

This important journal, initiated in 1945, appears irregularly when enough papers have accumulated to warrant. Volume II contains 1) Holger Madsen's Study on the Nematodes of Danish Gallinaceous Game Birds (pp. 1–126); 2) Johs. Andersen's Analysis of a Danish Roe-Deer Population based upon the extermination of the total stock (pp. 127–155); and 3) F. Jensenius Madsen's on the Food Habits of the Diving Ducks in Denmark (pp. 157–266). Part I of Vol. 3 is Andersen's study on the Food of the Danish Badger (pp. 1–75). The papers are all in English with Danish summaries. It is impressive to see the quality and thoroughness of the Danish wildlife research reported here. Wildlife ecologists interested in population dynamics will be particularly interested to see Andersen's Roe-Deer study—the deer population on the area was 1 per 8 acres, and almost the entire population (213) was shot preparatory to restocking from another source. This gave a unique opportunity to study the age and sex distribution of an entire population. The annual rate of increase, based upon fawn-adult ratio was 62 per cent.

Union of South Africa. Provincial Administration of the Cape of Good Hope. Department of Nature Conservation (Incorporating the Department of Inland Fisheries). Report No. 10 (1953). 68 pp.

This annual report, together with a number of other publications, demonstrate an interesting and impressive variety of conservation work being conducted. Those in pond fish work will be interested in the program in this field described for Cape Province.

An Evaluation of the Red Fox. By Thomas G. Scott. Natural History Survey Division, Urbana, Illinois. Biological Notes 35. July, 1955. 16 pp. Illus.

Nutritional Requirements of White-tailed Deer for Growth and Antler Development. By C. E. French, L. C. McEwen, N. D. Magruder, R. H. Ingram and R. W. Swift. Pennsylvania State University, College of Agriculture, Agricultural Experiment Station, University Park, Pennsylvania. Bulletin 600 and 600P. July, 1955. 50 pp. and 8 pp. respectively. Illus.—G. A. SWANSON.

BRIEFER ARTICLES

MOVEMENTS OF TAGGED BEAVER [1]

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Most observations on the movements of beaver have been based on transplanted animals which may give an atypical picture, or the beaver were marked in such a way that the mark was not recognized as such by persons not intimately familiar with the study. Distant recapture records were thus lost. The present study is an attempt to add to our knowledge of normal movements of this fur bearer.

The field work was supported by a grant-in-aid from the University of Minnesota Graduate School. Special thanks are due to the Minnesota Conservation Department for permission to work in the St. Croix State Park and to Mr. Harvey Scheer, Superintendent of this park, for his complete cooperation throughout the study.

During the summers of 1949, 1950 and 1951 forty-four beaver were live trapped, tagged and released at the point of capture on the streams in the St. Croix State Park in Pine County, Minnesota (Table 1). In 1949 the trapping was conducted in the early part of September and during June in 1950 and 1951. Most of the live trapping was carried out on Bear Creek because of its accessibility and the concentration of beaver there. Forty-three of the beaver tagged were from the eleven colonies known to exist on this stream.

TABLE 1.—INITIAL TRAPPING AGE AND RETURNS FROM THESE BEAVER DURING SUBSEQUENT TRAPPING PERIODS

Estimated age when tagged	Number tagged	No. live trap returns from the park	Trapper returns from outside the park	No. not retaken
Kits	2	0	1	1
Yearlings	28	1	9	18
2-year-olds	3	1	0	2
Adults	11	3	0	8
Total	44	5	10	29

Live trapping was stopped in 1952 because of a nearly complete die-off on the study area. This die-off apparently took place during the spring and summer of that year. Although a moderate amount of sign was seen in May of 1952 very little was found during the following September. A thorough examination of the eleven colonies at the latter date showed an occasional track, three trees cut and no repair work on any of the dams. Two beaver were found dead. This was apparently part of the general epizootic which was reported for Minnesota by Stenlund (J. Wildl. Mgt., **17**: 376–377, 1953) and for Wisconsin by Knutson (Wisc. Cons. Bull., **18**: 20–23, 1953).

The animals were trapped in Bailey-type live traps and ear tagged with No. 3 self-piercing fish tags. They were sexed, as far as possible by probing for the baculum and looking for the teats on the adult females (Bradt, J. Mamm. **19**: 139–162, 1938). They were aged on the basis of weight. Any animal weighing less than ten pounds was considered a kit, those weighing from 12 to 26 pounds were considered yearlings, and those over 30 pounds were considered adults. The classification of the population into kits, yearlings and older animals seemed to be quite easy but the separation of the two-year-olds from the older adults was difficult.

Of the 44 animals tagged, 10 were subsequently taken by trappers in Minnesota and Wisconsin and 11 were recaptured one or more times during the live trapping operations (Table 2).

Only two of the 44 beaver were first handled as kits. One of these (No. 4) was first trapped in colony "F" near the mouth of Lost Creek and was subsequently retaken by a trapper in southern Burnett County, Wisconsin, in February of 1951. Since it was first captured as a kit in September of 1949 and retaken before the break-up of ice on the rivers in 1951 it could hardly have made its immigration later than the fall of 1950.

Twenty-eight beaver were tagged as yearlings during the three years' trapping. Of these one was retaken in the park and nine were trapped from outside the park. In fact all of the trapper returns, except the one just discussed, were first handled as yearlings. Five of the trapper returns were taken in the vicinity of the park and five from considerable distances in Wisconsin. These latter were taken at airline distances of up to about 31 miles and stream distances of up to about 51 miles from the point of original capture (Table 2).

Only one of the beaver tagged as a yearling was recaptured in subsequent years in the park. This male, No. 14, was recaptured as a three-year-old in a colony about two miles downstream from where

[1] Paper No. 3144, Scientific Journal Series, Minnesota Agricultural Experiment Station, St. Paul 1, Minnesota.

TABLE 2.—RETURNS FROM BEAVER TAGGED IN THE ST. CROIX STATE PARK

Tag No.	Sex	Date tagged	Colony	Wt. at tagging	Estimated age at tagging	Recapture data			Distance traveled in miles	
						Date	Wt.	Area	Direct	By water
3	..	Sept. 9, 1949	F	24	yearling	March, 1953	..	Polk Co., Wisc.[2]	23	29.
4	..	Sept. 9, 1949	F	7	kit	Feb., 1951	..	Burnett Co., Wisc.	19	51.
7	♂	June 9, 1950	D	15	yearling	June 10, 1950	..	Colony C	.5	.7
..	..	.....	..	..	.....	June 17, 1950	..	Colony B	.2	.3
..	..	.....	..	..	.....	Spring, 1951	..	Pine Co., Minn.[2]	3	4
8	♂	July 11, 1950	E[3]	40.5	adult	June 17, 1950	41	Colony B	1.2	2.0
10	♀	Sept. 2, 1949	D	47.	adult	Sept. 9, 1949	..	Colony D	0	0
14	♂	Sept. 4, 1949	B	25.	yearling	June 16, 1951	..	Colony J	2.6	6.5
17	♀	June 8, 1950	D	20.5	yearling	Nov. 1950	..	Pine Co., Minn.[2]	8	9
23	♂	Sept. 3, 1949	J	26	yearling	March, 1954	33[1]	Polk Co., Wisc.[2]	31	41
25	♀	Sept. 10, 1949	J	46	adult	June 24, 1950	..	Colony J	0	0
..	..	.....	..	..	.....	June 16, 1951	..	Colony J	0	0
27	♂	June 21, 1950	G	21	yearling	Apr. 12, 1953	..	Douglas Co., Wisc.[2]	28	39
29	..	June 13, 1950	G	17	adult	June 17, 1950	..	Colony H	.3	1.
30	♂	June 20, 1950	G	35	two-years	June 12, 1951	41	Colony G	0	0
33	♀	Sept. 13, 1949	K	41	adult	June 22, 1950	38.5	Colony G	1.5	4.0
35	♂	June 25, 1950	E	17	yearling	Nov. 1950	..	Pine Co., Minn.[2]	3	7
36	..	June 12, 1950	K[3]	17	yearling	June 13, 1950	..	Colony G	3.5	3.0
44	♀	June 23, 1950	K[3]	21.5	yearling	Apr. 29, 1951	36[1]	Pine Co., Minn.[2]	2	7
49	..	June 25, 1950	E	18	yearling	Nov. 1950	..	Pine Co., Minn.	6	13
81	♂	June 5, 1951	E[3]	18	yearling	June 12, 1951	..	Colony H	.5	1.2
83	♂	June 4, 1951	E[3]	19	yearling	June 8, 1951	..	Colony E	0	0
84	♂	June 4, 1951	C[3]	21	yearling	March, 1953	..	Burnett Co., Wisc.[2]	31	36

[1] Weight reported by trapper.
[2] Trapper returns.
[3] Taken above the active portion of the colony.

it had been tagged. Six animals tagged as yearlings were retaken one or more times in the park during the same trapping period. These animals showed a considerable tendency to wander. For instance No. 7 was taken in the ponds of three different colonies during a period of nine days. The first and last colonies were about one mile apart.

None of the 14 beaver first captured as adults or two-year-olds were reported as having been taken outside of the park area. Three were retaken by live trapping in subsequent years within the park. One of these, No. 25, an adult female, was captured three years in a row at the same trap site. Number 33, an adult female, was taken in 1949 and 1950 in colony "G". In 1949 an adult male was also trapped in this colony but was accidentally drowned. In 1950 a male, No. 30, estimated to be two years old, was taken in the same pond. In 1951 this second male was retaken within 100 yards of where it had been taken the previous year. We were unable to recapture the female but small kits were found in a bank den. It is assumed that the original female was still in the colony.

In 1950 an adult female carrying two embryos was accidentally drowned at colony "I" but the male was not taken. In 1951 this colony was not in use.

The number of tagged animals and the number of returns from them is too small for the drawing of definite conclusions on beaver movements and colonization but several suggestions can be made. In making these suggestions it must be borne in mind that the St. Croix Park is a refuge on which trapping is not permitted although the adjacent areas in both Minnesota and Wisconsin are trapped regularly. The population on Bear Creek within the park area appeared to be at or near the maximum that social tolerances and suitable habitat would permit.

In the case of the kits there seems to be little doubt but that they were first taken at the colony in which they were born. This, of course cannot be assumed for those first taken as yearlings.

These data suggest that yearling beaver do a great deal of traveling and may establish themselves in new areas. One beaver first handled in the park as a kit and three as yearlings were retaken by trappers outside of the park at such dates that they could not have been older than yearlings when the movement took place.

The lack of returns from adult beaver outside the park area suggests little immigration by this class. The two cases of trap mortality indicate that the female is the important individual in establishing and maintaining the colony. When the male was lost a new male took over but when the female was lost the colony was abandoned.

The general tendency for beaver to move indicates that seed-stock refuges may be important on areas where beaver are desirable and where they may be trapped heavily.

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THE USE OF AGRICULTURAL COVER CROPS IN SOUTHEASTERN WATERFOWL MANAGEMENT

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Increased demand on southeastern land available for waterfowl management calls for the maximum production of hard seed and green forage to support the winter concentration. Agricultural cover crops can contribute to this program. By cover crops is meant fall-planted annuals, usually following summer non-legume crops and plowed under the following spring for soil improvement. The use of these cover crops for physical soil protection and the addition of nitrogen and humus is well known, but their value as waterfowl forage has often been overlooked.

In addition to their indirect value of increasing soil fertility and crop production, several cover crop species, properly used, can furnish good grazing for all species of geese and are subject to limited use by ducks. Their use can convert fields which supported summer crops of no waterfowl food value—such as cotton and tobacco—into excellent winter goose range. Used behind good waterfowl food crops, such as corn, peanuts, or grain sorghum, and coupled with gleanings from these crops or amounts deliberately left in the field, they can furnish an ideal combination of hard seed and green forage on the same site. The material for this paper has been gathered from various southeastern refuges of the U. S. Fish and Wildlife Service, from state-managed public hunting areas, and from private and club-owned land throughout the Southeast.

In some southeastern localities, wheat, oats, rye, barley and ryegrass are occasionally used as winter cover crops. These have no nitrogen-fixing properties but do furnish physical protection and add humus when plowed under. All are good goose forage.

Among the legume cover crops, only three species are subject to heavy goose usage. These are crimson clover, Austrian peas, and button clover. Crimson clover is especially well adapted to better soils in the central parts of this region, but in recent years its use has spread over much of the Southeast. When used as a cover crop, the reseeding strain offers no advantage over the common annual type. Austrian peas seem especially adapted to Piedmont and Upper Coastal soil types. A variety, the Dixie wonder pea, may offer certain advantages in some localities. Button clover is less well used by waterfowl than the above species, but is subject to enough usage to make planting worthwhile. It has an added disadvantage of making little growth in winter.

The vetches are excellent cover crops for the northern part of this region and Caley peas do well on Black Belt soils, but neither are used well enough by geese to justify planting for waterfowl forage. Occasionally, when hard pressed for green food and plants are in the right stage of succulence, they may receive light usage. A mixture of small grain with these legumes will increase their waterfowl value. Blue lupine, a cover crop used for Lower Coastal Plain soils, is without waterfowl food value. Several other legumes are in local or limited use as cover crops in the Southeast. These include the yellow lupine, the trefoils, and Singletary peas. Their waterfowl food value, if any, is not known.

When planting cover crops, the recommendations of the nearest agricultural substation as to inoculation, liming, fertilization, and dates of planting should be followed. With early maturing summer crops, it is often possible to break or disc fields before a cover crop is planted. With late-maturing summer crops, it may be necessary to drill cover crop seed in middles after the last cultivation.

To adapt cover crops to waterfowl use, only slight modifications of standard agricultural practices are necessary. Fields should be of sufficient size and shape to give feeding birds a feeling of security and should be located within reasonable proximity to water. They should be free of hedgerows, standing trees, and clumps of brush. All stalks, weed growth, and other possible predator cover should be leveled, using a rotary mower or similar implement. If extremely heavy waterfowl use is anticipated, the rate of seeding should be increased by 50 per cent above that normally recommended. When small grain or ryegrass are used as cover crops, the time of planting is an important factor. Too early seeding may result in a stand too coarse for good forage by the time migrant birds arrive. Too late planting may result in a young, poorly rooted stand that will be damaged by heavy waterfowl use. Planting at about the mid-date of the recommended planting period is usually best. The legumes are notoriously slow growers in cold weather, and it is usually best to plant at the earliest practicable date to insure against waterfowl damage to poorly rooted stands and to provide the appearance needed to attract geese. To promote good legume growth, proper inoculation and heavy fertilization are desirable.

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THE USE OF LOG TRANSFORMATIONS IN ANALYZING FALL ROADSIDE PHEASANT COUNTS[1]

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In 1952 an analysis of the fall roadside pheasant census in Iowa was made for a 15-year period (Kozicky, *et al.*, 1952) and certain conclusions were reached on the efficiency of sampling design as well as on the importance of sample size in predicting population trends within certain specified confidence limits. The analysis of variance (p. 298) was calculated on the basis of "the number of pheasants seen per 15-mile length of road" and segregated into outgoing and/or returning segments. While the usual assumption for such an analysis of variance is the constancy of error variance for the various segments into which the data have been decomposed, both table 3 (p. 299) and Fig. 3 (p. 302) indicate that there is a tendency for the experimental standard deviation *not* to be approximately constant but rather to vary in proportion to the segment means. Therefore, it appeared worthwhile to check on the findings of the analysis of variance by redoing it for the logarithms of pheasant counts, which is the standard procedure in such a situation, (Bartlett, 1947).

Theoretically, if x stands for the number of pheasants observed per mile and there is a linear relation between the standard deviation σ_x and the mean value μ_x of the form $\sigma_x = a + b\mu_x$, the transformation to be used is given by $y = \text{Log}(a+bx) = \log b\,(x+a/b) = \log(x+a/b) + \log b$ in which the constant log b can, of course, be omitted. Some difficulty was encountered in deciding on the value of a/b. Figure 3 (p. 302) gives some help here in that it shows that a/b is small compared with μ_x and that different choices of a/b in the transformation would all be fairly effective as transformations of x to approximately constant variance.

The choice of a/b suggested by fig. 3 is a/b = 0.150. Using this value we have as a variate transformation $y = \log(x+0.150)$ or with $u = 15x$ = No. of pheasants observed on a 15 mile section ($0.15 \times 15 = 2.25$ or 2 to the nearest integer)

$Y = \log 1/15\,(u+2) = \log(u+2) - \log 15$

If n is now the number of pheasants observed on a section of mileage, m (which was usually close to 15 miles), we use finally the convenient approximate working formula

$$y = \log(n+2) - \log m$$

The analysis of variance results are set out in Tables 1 and 2 below. These correspond to Table 2 (p. 298) of the above paper. Table 1 below deals with the separate analysis of the counts on the outgoing (O) and returning (R) routes whilst Table 2 gives the combined analysis. The mean squares are now in logarithmic units and are not directly comparable with the ones for 'pheasants per 15 mile route' on p. 298, but in Table 2 we have given the variance ratios F against the 'Remainder' as error for all components of variance and have set out alongside the corresponding F ratios for the analysis of p. 298 of the paper. In addition to equalizing the variance there is evidence that the additive assumption is better satisfied for the logarithmically transformed counts as is evidenced by reduction in a number of interactions, namely, (O versus R) × Years and (O versus R) × Counties and the increment of the year main effect.

If, again, we use the Routes within counties and years component to compute errors for yearly indices of pheasant counts, we reach conclusions that are almost identical with those reached on pp.

TABLE 1.—ANALYSIS OF VARIANCE FOR THE FALL ROADSIDE CENSUS FOR 99 ROUTES IN 33 IOWA COUNTIES

(logarithms of counts, separate analysis for outgoing and return segment)

	d.f.	Mean Sq.
SEGMENT O		
Years	4	4.806 461
Counties	32	0.371 738
Counties x Years	128	0.167 899
Segs. within Counties	66	0.154 726
Segs. within Counties x Years	260	0.094 950
	490	
SEGMENT R		
Years	4	6.020 068
Counties	32	0.470 454
Counties x Years	128	0.143 458
Segs. within Counties	66	0.157 678
Segs. within Counties x Years	260	0.083 123

[1] Journal Paper No. J-2533 of the Iowa Agricultural Experimental Station, Ames, Iowa. Proj. 497. Fish and Wildlife Service (U. S. Department of Interior), Iowa State College, Iowa State Conservation Commission, and the Wildlife Management Institute cooperating.

[2] Professor, Department of Statistics; Professor, Department of Statistics; and Leader, Iowa Cooperative Wildlife Research Unit, Department Zoology and Entomology.

TABLE 2.—COMPARISON OF THE ANALYSES OF VARIANCE FOR BOTH SEGMENTS COMBINED FOR THE FALL ROADSIDE CENSUS FOR 99 ROUTES IN 33 IOWA COUNTIES

Segments O and R		d.f.	Mean Square		F-ratio against Remainder
a. Analysis of Variance (Log transformed data)					
Years	Y	4	10.461 733		212.5
Counties	C	32	0.757 109		15.4
Counties x Years	YxC	128	0.235 698		4.8
Routes within Counties and Years	R + (RxC) + (YxR) + (YxRxC)	326*	0.166 418		3.4
Routes within Counties	R + (RxC)	66		0.269 448	5.5
Routes within Counties x Years	(YxR) + (YxRxC)	260*		0.140 264	2.8
Outgoing Seg. Versus Ingoing Seg.	S	1	2.446 284		49.7
(O Versus R) x Years	SxY	4	0.364 796		7.4
(O Versus R) x Counties	SxC	32	0.085 083		1.7
Remainder		454	0.049 229		
b. Analysis of Variance (Kozicky, *et al.*, 1952)					
Years		4	12,555.10		107.4
Counties		32	1,858.75		15.9
Counties x Years		128	588.86		5.0
Routes within Counties and Years		328	378.45		3.2
Routes within Counties		62**		602.89	5.2
Routes within Counties x Years		264		325.74	2.8
Outgoing Seg. Versus Ingoing Seg.		1	5,413.82		46.3
(O Versus R) x Years		4	1,655.99		14.2
(O Versus R) x Counties		32	1,388.61		11.9
Remainder		458	116.92		

* Analysis (a) incorporates a slight alteration in the degrees of freedom reduction for missing values.
** Four degrees of freedom substracted because 4 missing values were estimated.

298 last paragraph and 299:—A 20% difference in pheasant count (i.e., a log difference of $\log_{10} 1.2 - \log_{10} 1 = 0.08$) is required to indicate a population difference for two years, i.e., sample means of 33 x 3 x 2 (15-mile)-routes, and similarly the remaining conclusions are confirmed. We have, therefore, not achieved a decrease in average variance but merely an elimination of its heterogeneity.

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RED FOX FOOD HABITS IN THE VICINITY OF A VULNERABLE CAPTIVE GOOSE FLOCK

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A flock of 82 pinioned Canada Geese (*Branta canadensis*) is being held in a 22-acre enclosure on the Upper Souris National Wildlife Refuge near Foxholm, North Dakota. Red foxes (*Vulpes fulva*) are common on the refuge, and efforts are made to keep their numbers down in the vicinity of the goose pen.

The 6-foot wire netting about the pen has a graduated mesh, varying from openings of 1 inch at the bottom to about 6 inches at the top. Foxes pass through this fence about 30 inches above the ground where the openings average about 4 by 5 inches.

On December 18, 1953, after a period of relatively

mild winter weather, the fox trails in and about the goose pen were checked to note whether the geese were being disturbed. A water channel through the pen was covered with about 3 inches of ice, and a cover of newly fallen snow provided good tracking. A waterhole, previously kept open by the action of the geese, had frozen over and would support the weight of a man.

A fox track, revealing entry of a fox through the pen boundary fence about 1/8 of a mile from the concentrated geese, led almost direct to the goose flock on the ice. The track approached to the edge of the flock, but showed no signs of intermingling with the geese. The geese had a circle of about 30 feet trampled down over the frozen waterhole. There was no indication that the presence of the fox had alarmed the birds, although the tracks had approached to within 10 feet of the trampled-down area. The tracks showed that the predator had hesitated at the edge of the flock and had turned around there. The tracks then led directly away from the flock to the nearby shoreline, where typical mouse-hunting behavior started. About 100 yards northeast of the geese the fox made a 90-degree left turn and ran about 30 yards. At this point he crouched and apparently crept to a mouse nest. The nest was exposed on the snow with a few kernels of corn showing. Apparently the mouse had been caught and eaten. The tracks led from there northward out of the pen.

Two other cases of mouse-hunting by foxes in this goose pen were observed. The above-mentioned occurrence, however, was the only case where the fox exhibited an interest in the geese and then turned to mice for food.

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FISH PREDATION BY THE OTTER IN MICHIGAN[1]

Richard A. Ryder

To further understand the relationship of the otter, *Lutra c. canadensis*, to game fish in Michigan, 75 otter stomachs were analyzed for their food contents as an extension of the work of Lagler and Ostenson (1942). These stomachs were obtained from the Game Division of the Michigan Department of Conservation by Ostenson and comprised a portion of the otter trapped in the Lower Peninsula of Michigan during the 1942 and 1943 trapping seasons. Of the 75 stomachs analyzed, 54 contained at least a trace of food. There were 25 of these from non-trout waters, 21 from trout waters and 8 from unclassified areas. The classification of these waters was made by A. S. Hazzard and K. F. Lagler. The techniques used were those of Lagler and Ostenson (1942).

Interestingly, plant remains occurred with the greatest frequency of any material in the stomachs. It is believed however that much of the plant material was taken by the otter after it was trapped; several of stomachs from such animals were otherwise empty. Some of the vegetable matter was also probably taken accidentally while the otter foraged along the stream bottom in search of crayfish, mudminnows, and other bottom organisms.

Of the fish found, game and pan fishes were observed in 40.7 per cent of the stomachs (Table 1); most of these were centrarchids. Trout were found in only 13 per cent of all the stomachs and in only one-third of the stomachs from trout waters. None of the trout were estimated to be of legal length (7 inches) or greater. Forage and "noxious" fishes occurred in 55.5 per cent of the stomachs and were composed mostly of sticklebacks, mudminnows, and minnows. In both trout and non-trout waters forage fishes were greater both in numbers and in frequency of occurrence than were the game fishes.

The next two food items of importance were crayfishes and amphibians, with a percentage frequency of 22.2 and 16.7, respectively. The numbers of insects were next in abundance (13.0 per cent) but made up only a small volume.

It was difficult to determine whether the insects constituted a primary or secondary food of the otter. Large insects such as *Lethocerus*, *Belostoma*, and some of the tipulid larvae were, without a doubt, pursued, captured and ingested by the otter. Certain others, including chironomid larvae and other small insects, could not conceivably repay the otter in food value for energy expended in obtaining them; these were not enumerated but were considered to be the remains of food organisms eaten by the fish represented in the stomachs.

The findings of this study (Table 1) substantiate those of Lagler and Ostenson, 1942. A combination of their data with those of the present study presents a more complete picture of the spring food habits and fish predation by otter (Table 1).

Some general conclusions that can be drawn from this study are:

1. Apparently the otter captures fish, eat least to a certain extent, in proportion to their abundance in the waters. Thus, the relatively numerous forage

[1] Contribution from the Department of Fisheries, School of Natural Resources, University of Michigan.

TABLE 1.—FOOD OF OTTERS FROM MICHIGAN WATERS

	Data from present study		Present data combined with those of Lagler and Ostenson (1942)	
Food Item	No. of individuals	Percentage frequency	No. of individuals	Percentage frequency
Game and Pan Fishes	38	40.7	172	32.6
Other Fishes	203	55.5	639	56.4
Fish Remains	...	27.8	...	34.3
Amphibians	16	16.7	53	16.3
Crayfishes	13	22.2	77	32.2
Insects	11	13.0	36	13.2

Annotated list of food items and their enumeraticns (present work only).

GAME and PAN FISHES: Salmonidae, 8; *Ameiurus nebulosis*, 1; *Ameiurus* sp., 7; *Perca flavescens*, 4; *Lepomis gibbosus*, 1; *Lepomis macrochirus*, 3; Centrarchidae 14; OTHER FISHES: Petromyzontidae, 3; *Amia calva*, 1; *Catostomus commersoni*, 1; Catostomidae, 7; *Pimephales notatus*, 1; *Notemigonus crysoleucas*, 3; *Campostoma anomalum*, 1; *Chrosomus eos*, 13; *Notropis heterodon*, 1; *Notropis heterolepis*, 1; *Semotilus atromaculatus*, 1; Cyprinidae, 10; *Umbra* limi, 64; *Etheostoma exile*, 6; Etheostomatinae, 2; *Cottus* sp., 2; *Eucalia inconstans*, 79; AMPHIBIANS: *Rana clamitans*, 1; *Rana pipiens*, 8; *Rana* sp., 6; Anura, 1; CRAYFISHES: *Orconectes virilis*, 1; Cambarinae, 12; Amphipoda, 1; INSECTS: Dytiscidae, 1; Coleoptera, 9; Ephemeroptera, 3; *Belostoma* sp., 1; *Lethocerus* sp., 1; *Lethocerus americanus*, 2; *Notonecta* sp., 1; Corixidae, 3; Hemiptera, 1; Trichoptera, 1; *Sialis* sp., 1; Tabanidae, 1; Tipulidae, 4; Tendipedidae, 1; SPIDERS: Arachnida, 3; MOLLUSKS: Pelecypoda, 1.

fishes bear the brunt of the attack, whereas the normally less abundant fishes are not taken as frequently.

2. Fishes are probably captured by the otter in inverse proportion to their swimming ability. Hence the slower swimming mudminnows and sticklebacks are captured more frequently than the faster swimming trout.

3. The predatory habits of the otter may actually benefit trout by removing the less desirable (and usually slower moving) competitive and "noxious" fishes from trout waters.

4. On any but the smallest of streams or trout ponds, the depredations of the otter seem to be insignificant even when a maximum population density of otter is attained.

5. Fishes, crayfishes, and amphibians are the three primary spring foods of the otter in Michigan in both numbers and volume, and other food items are taken only occasionally or in very small quantity.

The problem of the otter in Michigan might best be left as it is. Despite the fact that this mammal is rarely seen in the wild because of its secretive habit, it is doubtful that it is nearing extinction. Rather, in many areas the numbers of otter may be close to maximum density. If this mammal becomes scarce again, it will not pay the trapper in time or effort to trap it, and, as a result there will be a release of pressure on the population. If the species increases greatly, the trappers will reap a greater harvest because more sets will be made specifically for otter and more otter will be taken accidentally in beaver sets. Hence, an artificial balance is established between the otter and the trapper. It is hard to conceive that the otter will ever become extinct in Michigan through trapping alone, but rather through the encroachment of civilization which will eliminate much of its natural habitat.

It is concluded from the foregoing study that the best management plan for the otter-trout relationship in Michigan is to further publicize the problem and to educate the various groups of people who are interested.

I am very grateful to Dr. Karl F. Lagler for suggesting this study, for providing the material with Dr. Burton T. Ostenson's consent, and for help in the identification of fish remains and in preparation of the manuscript. Dr. J. Speed Rogers has my thanks for identifying many of the insects and Dr. William H. Burt for help on the manuscript.

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AN INSTANCE OF SCABIES IN THE MARTEN (*Martes americana*)

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In October, 1953, Mr. J. D. Williams, Game Warden at Terrace, B. C., sent in for diagnosis the pelt of a marten (*M. a. abietenoides*) suffering from a skin condition that was manifest largely by depilation. It had been taken in the wild by a trapper of that district.

This animal had a very heavy infestation of the mite *Listrophorus mustelae* (Megnin), a species previously reported from mustelids but supposed to be a non-pathogen feeding on hair grease.

It was not possible to determine the exact nature of the feeding activity of the mites. Slight skin exudate had dried in thin, scattered crusts but in general little skin damage was noticeable on the dried pelt. Hair from the neck and sides was abraded until only a ragged pile-like covering remained and in places the hair had been shed or torn off completely. It had not been shed as in cases of sarcoptic mange, but had been broken off or torn out either by tearing with the teeth, scratching or rubbing. The inference is that irritation had been severe but that skin puncture and secondary infection of the dermis had been involved to a very minor degree.

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SEVERE INFESTATION OF BLOW FLIES IN A RACCOON

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A raccoon (*Procyon lotor*) was observed in a weakened condition for several days at a farm a few miles east of Salisbury, Maryland. It was then caught and held in captivity for a few days. It continued to become weaker and on May 3, 1954, B. Mixon of the Maryland Department of Game and Inland Fish submitted it to us for study.

There was no evidence of trauma, either internal or external. The fur was matted over the right hind leg, the inguinal region, and over much of the left hind leg. Inspection revealed the presence of thousands of larvae of the green-bottle fly, *Phaenicia sericata*, (Meigen)[1] actively tunneling in and out of the skin and subcutaneous tissue. Muscle underlying infested skin appeared healthy and untraumatized. A few larvae were in corners of the eyes but none were found in other orifices. Gross and microscopic examination of tissue from the raccoon gave no indication of any acute process which might have led to its moribund condition. James (1947. The flies that cause myiasis in man. U. S. Govt. Print. Off.) and Hall (1948: The blowflies of North America. Thom. Say Foundation) indicate that *P. sericata* may vary in virulence, some strains becoming parasitic with an ability to invade healthy tissue. In all probability, the larvae described above hatched from eggs originally laid in a skin wound, although no evidence for this was found.

[1] Identified by Mr. C. W. Sabrosky, Section of Insect Identification, Entomology Research Branch, U. S. Department of Agriculture.

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UNUSUALLY HIGH RETURNS FROM FISH-TAGGING EXPERIMENTS ON TWO TVA RESERVOIRS[1]

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The first fish tagging experiment in the Tennessee Valley was conducted on Norris Reservoir in 1940 in order to find out how much of the fish crop was being harvested. In this initial investigation a total of 1,010 fish consisting of black bass, walleye, sauger, black crappie, and rock bass were jaw-tagged, and 198 (19.6 per cent) of the tagged fish were harvested by fishermen. The results of this study corroborated by creel censuses, fisherman counts, depth distribution studies, and limnological data provided a basis for adopting a year-round open season on Norris Reservoir in 1941.

Several tagging studies on various TVA reservoirs have been reported since 1941, and, in general, the percentages of tags returned have varied from 0.2 to 29.8. However, in unreported data from Watauga Reservoir in 1950 and from South Holston Reservoir in 1952 the percentages of tags returned were so much larger than any reported heretofore that they may be of special interest to other fisheries biologists.

The two reservoirs and their fish populations were similar. Watauga is 6,430 acres in area and has a spillway elevation of 1975 feet above sea level; South Holston is 7,580 acres in area and has a spillway elevation of 1742 feet above sea level. Watauga Dam was closed on December 1, 1948, and South Holston Dam was closed November 20, 1950. Fishing was not permitted in either reservoir for approximately 18 months from the date of closure of the dams. Accordingly, Watauga was opened to fishing on May 30, 1950, and South Holston on May 30, 1952.

Fish were tagged during May in both reservoirs just prior to the opening date for fishing. In both investigations sportsmen volunteered to catch the fish by hook and line for tagging, and all tagging was done by TVA and state fisheries personnel. In both experiments Number 3 Monel, strap jaw tags were affixed to the upper jaw of the fish.

The results of these tagging investigations are listed in Table 1.

For warm-water, jaw-tagged fish these returns were the highest known to the writer until recently when Stroud (personal communication) indicated that he had observed returns of 55–60 per cent in Massachusetts.

There was, no doubt, a combination of several factors which favored the return of large numbers of tags. One factor was created by the usual surge in abundance of the populations of certain river fishes following impoundment. The largemouth and smallmouth bass had apparently spawned and survived in great numbers. It may be that these fish were overtaxing their food supply by the time the first spring fishing season opened and were unusually susceptible to hook-and-line fishing.

When compared with similar data from other TVA waters (Miller, 1950; Manges, 1950a and 1950b) these return ratios suggest also that populations of black bass, and perhaps other predators such as walleye and sauger as well, typically undergo a relatively greater exploitation by angling than do such species as the crappies and other pan fish.

Another important influence on the return of tags was the persistent, unrelenting efforts of the press, radio, sportsmen's clubs, dock operators, sporting-goods dealers, and other individuals in stimulating interest in the tagging program. As a result of the efforts of these people, 95 per cent of the recovered tags in Watauga Reservoir and 94 per cent of the recovered tags in South Holston Reservoir were reported during the first year.

There is no evidence that the percentages of fish harvested during these investigations adversely affected subsequent fishing in these reservoirs.

TABLE 1.—NUMBERS AND KINDS OF FISH TAGGED IN EACH OF TWO TVA RESERVOIRS, TOGETHER WITH THE NUMBERS AND PERCENTAGES OF TAGS RETURNED

Reservoir	Species	Number tagged	Number tags returned	Percentage tags returned
Watauga, 1950	Largemouth bass	998	415	41.6
	Smallmouth bass	528	210	39.8
	Rock bass	94	36	38.3
	Black crappie	2	1	50.0
	Total	1,622	662	40.8
South Holston, 1952	Largemouth bass	279	115	41.2
	Smallmouth bass	104	44	42.3
	Rock bass	96	42	43.8
	Black crappie	16	3	18.8
	Bluegill	1	...	...
	Total	496	204	41.1

[1] Published with permission of the Tennessee Valley Authority.

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TECHNIQUE FOR IDENTIFICATION OF WOODCOCKS AT NIGHT

Wilmer C. Richter and Stephen A. Liscinsky

Pennsylvania Game Commission, Harrisburg

During the spring of 1954, the writers investigated the possibility of identifying individual woodcocks at night by means of reflective bands. Two birds trapped on their singing grounds were banded with a standard Fish and Wildlife Service band on one leg and with a 1/4″ band of 1/32″ aluminum alloy covered with Wide Angle Pressure Sensitive Flattop "Scotchlite" Reflective Sheeting on the other leg. One band was red and one was gold.

The bird marked with the red band moved from its singing ground after being trapped and was not relocated. The woodcock with the gold band was identified in the beam of a five-celled flashlight on several different nights following the original capture. Other woodcocks trapped during 1954 have been banded with silver "Scotchlite" bands, with the hope that some of these individuals might be "spotted" by investigators working on the winter range.

Because of a limited number of colors, the application of this technique for the determination of local movement and behavior is restricted, particularly in terms of individual birds. However, the use of the reflective material on wing bands, neck bands, etc., may permit greater versatility of the technique. One of the most practical applications of this method of marking would perhaps be for each state or province to have an assigned color, so that investigators on the breeding and wintering grounds could determine the origin of certain birds without having to catch or kill them.

Accepted for publication Sept. 16, 1954.

AN EFFICIENT HANDLING CRATE FOR WHITETAIL DEER

Edward J. Mikula

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Handling of large numbers of deer in connection with trapping and tagging operations requires a type of handling crate that will prevent undue injuries to the animals by immobilizing them as much as possible, and also facilitate rapid handling. A crate developed at the Cusino Wildlife Experiment Station appears to meet these requirements.

A crate originally designed by L. A. Davenport and E. F. Kellum had an egg-shaped hole about 13″ high and 8″ wide cut in one of the end doors to allow the deer's head and neck to protrude. Edges of the hole were padded with sponge rubber and covered with inner tube to provide a cushioning effect and prevent injury to the animal's head and neck. Three slits 4″ wide were then cut in the top on the rear portion of the crate. The wood strips between the slits were of 2″ stock and served as fulcrums for a pry-door. After a deer is driven into the crate, the pry-door placed progressively farther forward prevents the animal from retreating and holds it in one position. Recent modifications have been made in the light of further experience which have increased the crate's efficiency. The inside height has been cut from 48″ to approximately 36″. This reduces weight and protects the deer from injury in jumping upward. The hole in the end door has been reduced to 9½″ x 8″ which eliminates the tendency of the deer to stick its feet out. Turn-down handles have been added to make the crate easier to carry.

Thus far deer up to 200 pounds live weight have been handled readily in the new, smaller crate with a minimum of injury. The height could be increased if large animals are concerned. Details of the present crate are shown in the accompanying drawing.

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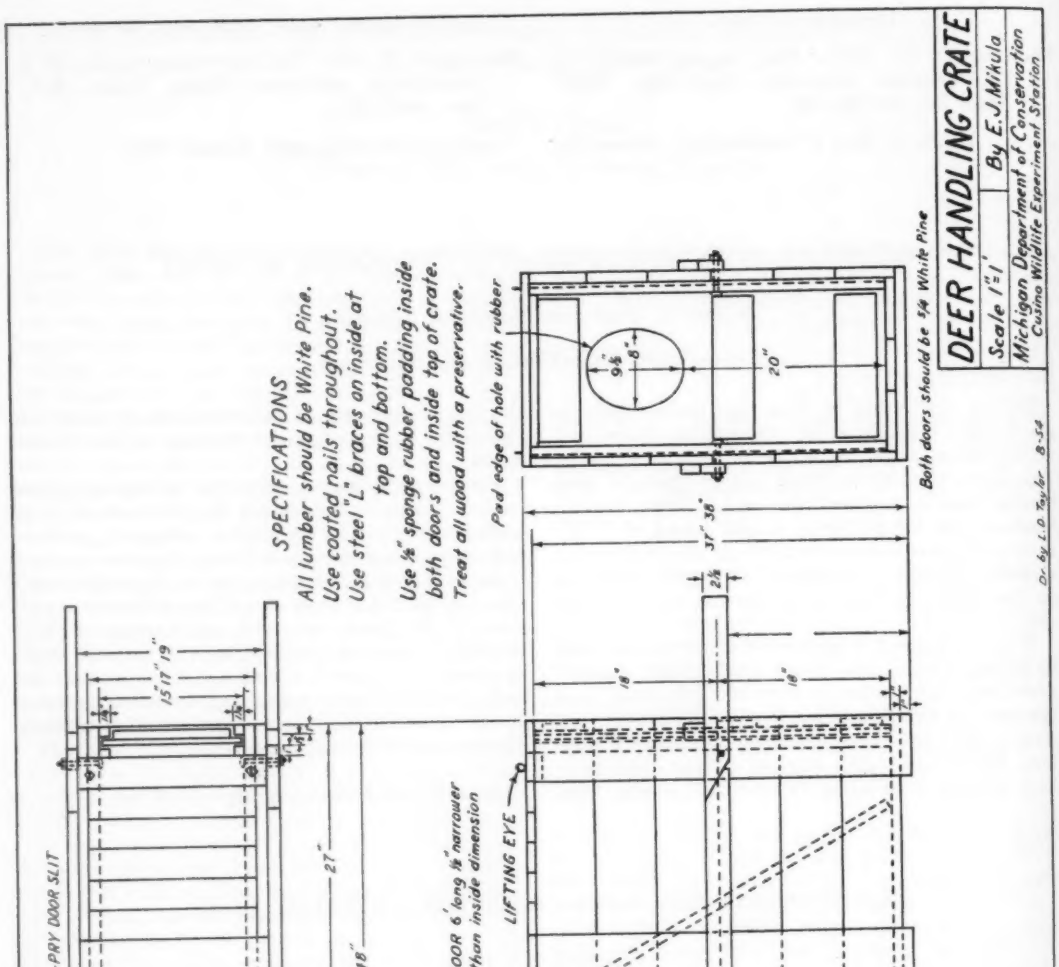
DEER HANDLING CRATE
Scale 1"=1'
By E.J.Mikula
Michigan Department of Conservation
Cusino Wildlife Experiment Station
Dr. by L.O. Taylor 8-54
SPECIFICATIONS
All lumber should be White Pine.
Use coated nails throughout.
Use steel "L" braces on inside at top and bottom.
Use ½" sponge rubber padding inside both doors and inside top of crate.
Treat all wood with a preservative.
Both doors should be 5/8 White Pine
Pad edge of hole with rubber
9½"
8"
20"
31" 3/8"
2⅛
18"
18"
PRY DOOR 6' long ½" narrower than inside dimension
LIFTING EYE
TURN DOWN HANDLE
Threaded end of carriage bolts must be on outside
PRY DOOR SLIT
15" 17" 19"
27"
48"
Open
Open
Open
3" 3" 3" 3" 3"

Michigan Department of Conservation
Cusino Wildlife Experiment Station
Dr. by L.D. Taylor 8-54

A HIGH REPRODUCTIVE RATE FOR ROCKY MOUNTAIN MULE DEER
(*Odocoileus h. hemionus*)

Wallace Jensen and W. Leslie Robinette

Utah State Fish and Game Department and U. S. Fish and Wildlife Service, Salt Lake City, Utah

Thirty pregnancy examinations of mule deer from northwestern Utah in 1954 revealed a high state of fertility (Table 1). Twenty-nine uteri were secured during a special hunt the first three weekends of January on the east end of the Raft River Mountains. Most of the deer wintering in this particular area summer in Idaho on the Black Pine and Sublett Divisions of the Minidoka National Forest. In addition, a single doe was killed in an alfalfa field by the senior author while on control work near Portage, Utah, which is very near the Idaho line, on July 15, 1954.

TABLE 1.—FETAL COUNTS FOR UTERI TAKEN FROM 30 DOES FROM NORTHWESTERN UTAH—1954

Age of Doe	No. Does Examined	No. Does With 0 Fetuses	1	2	3	Number Young Per Doe	Per Pregnant Doe
Fawns	5	4	1	0	0	0.20	1.00
Yearling	7	0	4	3	0	1.38	1.38
2-Year	1	0	0	1	0	2.00	2.00
3-Year	1	0	0	1	0	2.00	2.00
4-7 Year	8	0	0	7	1	2.12	2.12
8-Year Plus	4	0	0	3	1	2.25	2.25
Unclassified (but older than fawns)	4	1	1	1	1	1.50	2.00
Total or Average (excluding fawns)	25	1	5	16	3	1.84	1.92
Per cent	100	4	20	64	12	....	....

Despite a rather small sample, the fetal rate (1.84) for does older than fawns listed in Table 1, exceeds significantly (at the 1 per cent level) the reproductive rates obtained from other parts of the State and also exceeds any published accounts with which we are familiar for mule deer. The 14 does (older than yearlings) which were aged gave an exceptional rate of 2.14 young per doe. Even yearlings had an average of 1.38 young. There was at least a normal complement of yearlings (which usually have not yet attained full fertility) in the sample for they made up a third of the does which were aged. Four of the 25 does (older than fawns) were placed in an unclassified group because their heads had not been brought in to the checking station by the hunters. Two uteri from the unclassified does gave the appearance of having been virginal prior to the current season so it is very possible they were from yearlings also. Only one doe older than a fawn was found without young. This doe had apparently been crippled during a previous hunt for according to the hunters one hind leg was withered and badly infected. She was in such poor condition that the hunters left her in the field but did bring in the reproductive tract. An ovarian analysis revealed two pigmented scars in one ovary indicating pregnancy a year ago so her current lack of young could probably be attributed to an emaciated condition.

Three, or 12 per cent, of the 25 does older than fawns, were carrying triplets contrasting greatly with the one per cent found in about 1,000 other Utah does. An additional set of triplets was brought out by one of the hunters but could not be used for he had not been contacted on his way into the hunting area and had brought the triplet fetuses out only because of their rarity.

Four of the five fawn uteri were obtained from the Raft River area. None was gravid and no corpora lutea were found in the ovaries. The fifth fawn, however, which was killed 50 miles east of the Raft River Mountains by the senior author July 15, 1954 near Portage, Utah, was pregnant, carrying a single, nearly full-size fetus. This animal, although a yearling at the time of death, was a 1953 fawn as evidenced by a single pair of permanent incisors and third molars which had not yet erupted through the jaw bone. To our knowledge this is the first wild mule deer doe of this age which has been examined and found carrying young. Crane and Jones (Jour. Wildl. Mgt. **17**: 225, 1953) reported the case of a semi-captive doe giving birth to a single fawn when about 13 months of age at the Price Game Farm in Utah. Robinette, *et al.* (Jour. Wildl. Mgt. **19**: 115–136, 1955) report no pregnancies for 107 Utah fawns but did find indirect evidence of fawn breeding when 7 out of 167 sets of ovaries from yearlings were found containing pigmented scars. They further report that 3 of 540 yearling does examined apparently had had young inasmuch as the hunters removed their udders in field dressing them. The hunters stated that the udders of these three does were developed and contained milk.

Just what the reproductive rate for mule deer would be under optimum conditions is as yet unknown. However, it appears that it is being approached by deer in the northwestern part of the state. Added study is desirable to learn what factor or factors are contributing to the productiveness of this herd.

This note is a contribution from the Utah big game, livestock and range relationships study.

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ANOTHER WATERCHESTNUT INFESTATION

Alexander C. Martin

Fish and Wildlife Service, U. S. Department of the Interior

The recent discovery of a particularly threatening infestation of waterchestnut, *Trapa natans*, in the upper section of Chesapeake Bay, a few miles east of Baltimore, re-emphasizes the need for public familiarity with this pest and for watchfulness against its invasion of new areas.

The new outbreak marks the fourth main area of infestation in eastern United States. The other locations are in New York State (along the Hudson and Mohawk Rivers and in the southern end of Lake Champlain), Massachusetts (in the Sudbury, Concord, and Assabet Rivers), and the Potomac River. The conservation departments of New York State and Massachusetts have waged an uphill fight against the weed and, in the Potomac, it was only after nearly a decade of large-scale operations costing upwards of a half-million dollars that a large measure of control was obtained. If the new waterchestnut site in northern Chesapeake Bay should remain uncontrolled, it will undoubtedly infest other parts of the Bay, including one of the richest waterfowl feeding grounds on the continent: the Susquehanna Flats. Also, there is prospect that bathing resorts in many parts of the Bay would have to be abandoned because of the spiny seeds drifting onto the beaches.

The Chesapeake Bay location of the plant was discovered by Fish and Wildlife Service biologists on August 10, 1954. Comments by a local farmer indicate the probability that waterchestnut has been in this vicinity about four years. At present, four main beds are known, totaling about 100 acres. Two are in the Gunpowder River and two in its tributary the Bird River. One of the locations, Watson Creek, is within the Aberdeen Proving Grounds and the other three (Days Cove, head of Bird River, and a cove on the south side of Bird River) adjoin this restricted military zone.

Though not so widely abundant nor as well-known as the waterhyacinth, waterchestnut is in some respects even more pernicious. Not only did former luxuriant beds of waterchestnut along 40 miles of the Potomac River destroy fishery and waterfowl values but they also caused much harm in other ways. The heavy blankets of vegetation shackled navigation in shallow-water areas and abetted mosquito production. In addition, innumerable spined and barbed seeds deposited on or in sandy beaches, caused abandonment of many bathing resorts along the river.

The plant has sufficient distinctive features to make identification easy. Rosettes of floating leaves terminate slender, rope-like stems, the leaves being wedge-shaped, glossy, toothed on the outer margins and having distended stalks. Additional finely divided leaf-like structures occur below the surface

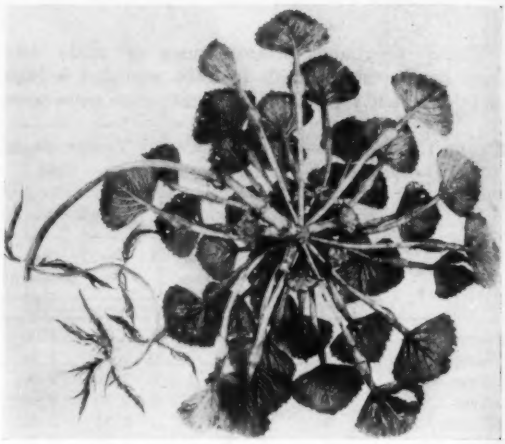

FIG. 1. Under side of waterchestnut rosette. *Courtesy Fish and Wildlife Service*

in lax whorls. In shallow water, the stems may be only a few inches long, whereas in greater depths they may attain 10 to 15 feet. Commonly the stems have branches, each terminating in a rosette. Small white flowers are followed by the large nut-like seeds (technically fruits), bearing stout spines which are armed near their tips by numerous minute barbs.

Waterchestnut generally grows in fresh, slow-moving streams or ponds but it tolerates slightly brackish conditions such as exist in tidal sections of the Potomac. It is an annual, depending solely on seeds for perpetuation. However, within a single growing season detached, well-developed rosettes are often able to take root on muddy margins and produce a crop of mature seeds. Most of one year's seed production germinates the following spring but seeds which remain dormant pose a threat of future re-infestation. Apparently, under favorable conditions some can survive for five years or more.

The stitch-in-time maxim applies to control of the waterchestnut menace. Once the plant has become established in dense beds and has produced crops of seeds, extermination is necessarily costly in both time and money. Though most of the Potomac infestation was cleared up years ago, the task is not yet complete and no one can predict accurately when it will be. As long as sporadic germination continues among seeds uncovered from silt during dredging operations, systematic patrolling must be maintained to locate and destroy isolated colonies of the plant.

The herbicide 2,4-D is now recognized as the most practical means of combatting beds of water-

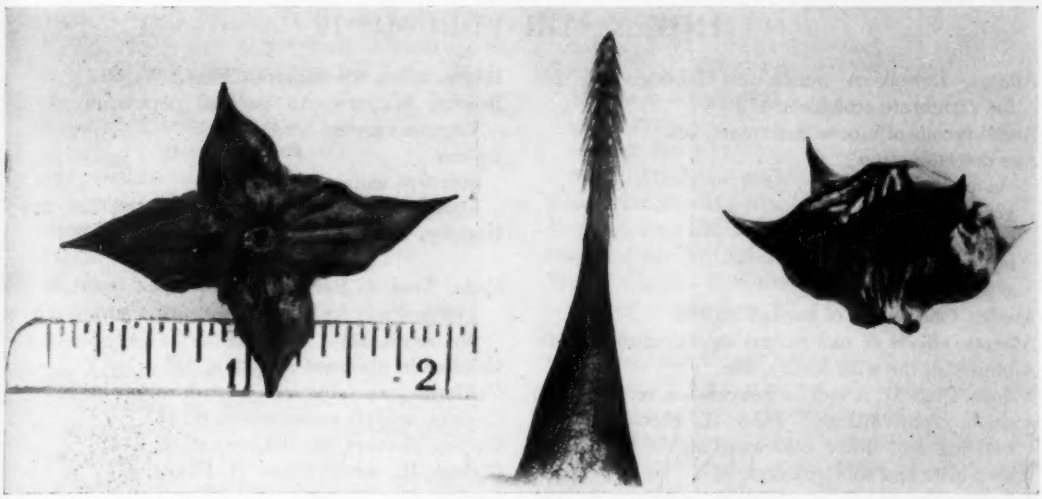

FIG. 2. Two views of the seed or nut with an intervening close-up of a single spine showing the barbs. *Courtesy Fish and Wildlife Service*

chestnut. Destruction of former beds in the Potomac was accomplished by a fleet of mowing machines, but this occurred before the time that 2,4-D was widely available. For scattered, small infestations, pulling by hand is often practical. Also, in early summer young plants can be destroyed by cutting about a foot below the water surface. Later cuttings are likely to be less effective and may require repetition in order to prevent seed production.

Good results with 2,4-D have been obtained at the rate of 8 pounds per acre of the acid equivalent and with 50 gallons of spray applied per acre. Oil or water solutions are nearly equally effective. Best results are likely to be obtained when the rosettes are so crowded together that much of the foliage is slightly above the water surface. Spraying with 2,4-D during two or three successive years can eliminate waterchestnut beds to the extent that remaining scattered plants can be pulled by hand. However, patrol and control may need to be maintained for an indefinite number of additional years in order to avoid loss of all ground gained.

In contrast to the tendency of this extremely obnoxious plant to prosper and spread on this continent, there has been some evidence that in Europe it has been disappearing. In a 1920 book on "Water Plants," the eminent botanist Agnes Arber wrote "It certainly seems to be a plant which is in process of extinction in various parts of its range, . . . The exact reason for its disappearance is hard to find." Since the situation in North America is quite the reverse and the plant is proving difficult to suppress here despite well-organized effort, the United States Fish and Wildlife Service has arranged with the State Department to contact European sources of information on the possible existence of an effective natural enemy of waterchestnut that may be curbing the plant over there.

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INDEX FOR VOLUME 19

Adams, Lowell. A punch-card bibliographic file for vertebrate ecologists, 472
Aerial census of moose in summer, 382
Age determination
  channel catfish, 243
  gray squirrel, 479
  mourning dove, 412
  muskrat, 463
  sage grouse, 267
Alaska, food habits of marten in, 364
Alberta, effects of hail storms on waterfowl in, 368
Albinism in the wild turkey, 408
Aldous, Clair M. A tool for beaver dam removal, 153
Aldrich, John W. and John H. Steenis. Neck-banding and other color-marking of waterfowl; its merits and shortcomings, 317
Atkeson, Thomas Z., see Givens, Lawrence S., 494

Bailey, R. Wayne. Notes on albinism in the eastern wild turkey, 408
  Two records of turkey brood survival after the death of the hen, 408
Bailey, William J., see Liscinsky, Stephen A., 405
Banding
  in waterfowl studies, 75
  recoveries from reward bands, 71
Bass, striped, in southeastern United States, 444
Bear, black, damage to redwood reproduction by, 437
Beaver
  movements of tagged, 492
  removal of dams of, 153
Beck, Doris O., see Beck, John R., 198
Beck, John R. and Doris O. A method of nutritional evaluation of wildlife foods, 198
Beckwith, Stephen L., see Michael, Victor C., 281
Beer, James. Movements of tagged beaver, 492
Bell, J. Frederick, George W. Sciple and A. A. Hubert. A microenvironment concept of the epizoology of avian botulism, 352
  see Philip, Cornelius B., 225
Bellrose, Frank C. A comparison of recoveries from reward and standard bands, 71
Benson, Dirck. Book review, 398
Bergeson, William R. Obituary, 485
Bibliographic file for vertebrate ecologists, 472
Big game, winter browse utilization by, 206, 215
Bobcat, food of, 249
Bobwhite, food of, 281
Bolin, F. M., see Eveleth, D. F., 152
Botulism, avian, 352
Bowman, Robert I. Aerial reconnaissance of moose in summer, 382
Brant, black, migration of, 321
Brohn, Allen, see Sampson, Frank W., 272
Brooks, Maurice. An isolated population of the Virginia varying hare, 54
Browse
  nutritive value of, 65
  winter utilization in wilderness range, 206, 215
Buckley, John L., see Lensink, Calvin J., 364

Cade, Tom J. Records of the black brant in the Yukon basin and the question of a spring migration route, 321
Calcium in pheasant nutrition, 325
California, reproduction of brush rabbit in, 177
Canada, wildlife conservation in, 161
Catfish, channel, age determination, 243
Cedeno, R., see McClure, H. Elliott, 477
Census
  cottontail rabbit, 466
  fox squirrel, 89
  moose, 382
  pheasant, 254, 495
Chance, Charles J. Unusually high returns from fish-tagging experiments on two TVA reservoirs, 500
Chatelain, Edward F. Obituary, 310
Conservation
  future of research, 1
  of wildlife in Canada, 161
Control, extension predator, 272
  waterchestnut, 504
Cooch, Graham. Modifications in mass goose trapping technique, 315
Coot, nesting of, in Manitoba, 189
Cottam, Clarence. Book review, 490
Cottontail
  introduction and distribution in Oregon, 184
  restocking in Pennsylvania, 61
Coulter, Malcolm W. Spring food habits of surface-feeding ducks in Maine, 263
Cowan, Ian McT. An instance of scabies in the marten, 499
  Wildlife conservation in Canada, 161
  and A. J. Wood. The normal temperature of the Columbian black-tailed deer, 154
Crane, Harold S., see Robinette, W. Leslie, 115
Crissey, Walter F. The use of banding data in determining waterfowl migration and distribution, 75

Dale, Fred H. The role of calcium in reproduction of the ring-necked pheasant, 325
Dalke, Paul D., see Hoskins, Leonard W., 215
Dams, removal of beaver, 153
Davis, W. B. Book review, 149

Davison, Verne E., L. M. Dickerson, Karl Graetz, W. W. Neely and Lloyd Roof. Measuring the yield and availability of game bird foods, 302
Deer
  black-tailed, temperature of, 154
    growth rate of, 331
  mule, fertility in Utah, 115
    high reproductive rate in, 503
  white-tailed, controlled hunts of, 346
    handling crate for, 501
    management, 143
    range appraisal in Ozarks, 358
Derby, James V., see DeWitt, James B., 65
deVos, Antoon. Book review, 315
DeWitt, James B. and James V. Derby, Jr. Changes in nutritive value of browse plants following forest fires, 65
Dickerson, L. M., see Davison, Verne E., 302
Disease
  aspergillosus in mallards, 415
  avian botulism, 352
  blow flies in raccoon, 499
  of emergent aquatic vegetation, 24
  parasites in jack rabbits, 225
  parasitic gastritis in elk, 152
  scabies in marten, 499
  skin tumors in gray squirrel, 402
  taking blood samples from living birds, 477
Distribution of cottontail in Oregon, 184
Dove, mourning
  age determination in, 412
  in North Dakota, 157
Ducks
  food habits in Maine, 263
  mallard, aspergillosus in, 415
  production, 36
Dunkeson, Robert L. Deer range appraisal for the Missouri Ozarks, 358
Dustman, Eugene H., see Stewart, Paul A., 403

Elk, Parasitic gastritis in, 152
Eng, Robert L. A method for obtaining sage grouse age and sex ratios from wings, 267
Erickson, A. B., see Krefting, L. W., 346
Eschmeyer, Reuben W. Obituary, 483
Eveleth, D. F. and F. M. Bolin. Parasitic gastritis of elk, 152

Fertility of mule deer in Utah, 115
File, bibliographic, punch-card, 472
Fire, effect of, on browse, 65
Fish loss in irrigation canals, 375
Fitch, Frank W. Jr., see Haugen, Arnold O., 297
Food availability, determination of, 297, 302
Food habits
  bobcat, 249
  ducks, in spring, 263
  marten in Alaska, 364
  quail, 281
  red fox, 496
  Rocky Mountain goat, 429
Foods, nutritional evaluation of wildlife, 198
Fox, red, food habits, 496
Freese, John W. Obituary, 149
Friley, Charles E. Criteria for estimating fall fox squirrel populations, 89

Gashwiler, Jay S., see Robinette, W. Leslie, 115
Geis, Aelred. Trap response of the cottontail rabbit and its effect on censusing, 466
Givens, Lawrence S. and Thomas Z. Atkeson. The use of agricultural cover crops in southeastern waterfowl management, 494
Glazener, W. Caleb. Book reviews, 399, 489
Glover, Fred A. Black bear damage to redwood reproduction, 437
Goat, Rocky Mountain, in Montana, 417, 429
Goose
  marking, 316
  trapping, 315
Graetz, Karl, see Davison, Verne E., 302
Graf, William. Cottontail rabbit introductions and distribution in Oregon, 184
Grouse
  prairie chicken abundance, 233
  ruffed, trapping, 405
  sage, age determination in, 267
Growth
  rate of, in channel catfish, 243
  rate of, in black-tailed deer, 331
Gunvalson, V. E., see Krefting, L. W., 346

Haller, Frank D. Obituary, 311
Hamilton, Lawrence S. Book review, 401
Hamilton, W. J. Jr. Book review, 399
Hare, varying, in Virginia, 54
Harris, Dave. Obituary, 397
Hartley, H. O., P. G. Homeyer and E. L. Kozicky. The use of log transformations in analyzing fall roadside pheasant counts, 495
Helm, Lewis G. Plastic collars for marking geese, 316
Hendrickson, George O., see Kozicky, Edward L., 136
Herman, Carlton M. and James R. Reilly. Skin tumors on squirrels, 402
  see Killam, Lawrence, 499
Hewitt, Oliver H. Book review, 399
    Editor's note, 443
Homeyer, Paul G., see Kozicky, E. L., 136
  see Hartley, H. O., 495

Hosford, Hallock Jay. Obituary, 484
Hoskins, Leonard W. and Paul D. Dalke. Winter browse on the Pocatello big game range in southeastern Idaho, 215
Hubert, A. A., see Bell, J. Frederick, 352

Idaho, browse in big game range, 215
Impoundment, effect of, on water temperatures, 47
Introduction
of cottontail in Oregon, 184
of European rabbit in United States, 8
Iowa, pheasant populations in, 136, 254

Jensen, Wallace and W. Leslie Robinette. A high reproductive rate for Rocky Mountain mule deer, 503
Jones, Dale A., see Robinette, W. Leslie, 115

Kalmbach, E. R. Book review, 486
Kiel, William H. Jr. Nesting studies of the coot in southwestern Manitoba, 189
Killam, Lawrence and Carlton M. Herman. Severe infestation of blow flies in a raccoon, 499
Klonglan, Eugene D. Factors influencing the fall roadside pheasant census in Iowa, 254
Kozicky, Edward L., George O. Hendrickson and Paul G. Homeyer. Weather and fall pheasant populations in Iowa, 136
see Hartley, H. O., 495
Krefting, L. W., A. B. Erickson and V. E. Gunvalson. Results of controlled deer hunts on the Tamarac National Wildlife Refuge, 346

Larson, Carl L., see Philip, Cornelius B., 225
Lensink, Calvin J., Ronald O. Skoog and John L. Buckley. Food habits of marten in interior Alaska and their significance, 364
Lentfer, Jack W. A two-year study of the Rocky Mountain goat in the Crazy Mountains, Montana, 417
Leonard, Justin W. The future of conservation research, 1
Lespedeza
bicolor as rabbit food, 324
bicolor, culture of, 84
seed, availability of, 297
Lewis, Harrison F. Book review, 313
Liscinsky, Stephen A. and William J. Bailey, Jr. A modified shorebird trap for capturing woodcock and grouse, 405
see Richter, Wilmer C., 501
Loss of game fish in irrigation canals, 375

Maine, spring foods of ducks in, 263
trout populations and fishery in, 336
Manitoba, nesting of coot in, 189
Map grids for field notes, 156
Marking
animals for night identification, 159
pheasants with neck tags, 414
waterfowl, 316, 317, 319
Marten
food habits in Alaska, 364
scabies in, 499
Martin, Alexander C. Another waterchestnut infestation, 504
Martin, Frank R. Red fox food habits in the vicinity of a vulnerable captive goose flock, 496
Marzolf, Richard C. Use of pectoral spines and vertebrae for determining age and rate of growth of the channel catfish, 243
Obituary, 485
Mayhew, Wilbur W. Spring rainfall in relation to mallard production in the Sacramento Valley, California, 36
McCabe, Robert A. Some data on Wisconsin pheasants obtained by interviewing farmers, 150
McClure, H. Elliott and R. Cedeno. Techniques for taking blood samples from living birds, 477
McCulloch, Clay Y. Jr. Utilization of winter browse on wilderness big game range, 206
McDonald, Malcolm E. Cause and effects of a die-off of emergent vegetation, 24
McDowell, Robert D. Restocking with "native" cottontails, 61
Michael, Victor C. and Stephen L. Beckwith. Quail preference for seed of farm crops, 281
Michigan
age determination of muskrats in, 463
predation on fish by otter in, 497
Mikula, Edward J. An efficient handling crate for whitetail deer, 501
Missouri
deer range appraisal, 358
extension predator control program, 272
Montana, Rocky Mountain goat in, 417, 429
Moose, aerial census in summer, 382
Mossman, Archie S. Reproduction of the brush rabbit in California, 177
Murie, Adolph. Book review, 147

Neely, W. W., see Davison, V. E., 302
Neff, Johnson A. Outbreak of aspergillosus in mallards, 415
Nelson, Lee K. A pheasant neck tag, 414
Nemes, John L. Obituary, 484
Nesting of coot in Manitoba, 189
Nevada, diseases and parasites of jack rabbits in, 225
North Dakota, mourning dove population in, 157
Nutritional evaluation
of wildlife foods, 198
effect of fire on browse, 65
calcium in pheasant reproduction, 325

Obituaries
Bergeson, William R., 485
Chatelain, Edward F., 310
Eschmeyer, Reuben W., 483
Freese, John W., 149
Haller, Frank D., 311
Harris, Dave, 397
Hosford, Hallock Jay, 484
Marzolf, Richard C., 485
Nemes, John L., 484
Shuman, Richard F., 309
Oklahoma, productivity of farm ponds in, 450
Oregon, cottontail rabbit in, 184
Otter, predation on fish in Michigan, 497

Parasites
and diseases in jack rabbits, 225
and gastritis of elk, 152
Partridge, Hungarian in Utah, 93
Partridge pea seed, availability, 297
Pasto, Jerome K., see Thomas, D. Woods, 143
Pheasant
calcium in reproduction of, 325
census in Iowa, 254, 495
flushing incubating, 403
in Wisconsin, 150
marking with neck tag, 414
weather and fall populations in Iowa, 136
Philip, Cornelius B., J. Frederick Bell and Carl L. Larson. Evidence of infectious diseases and parasites in a peak population of black-tailed jack rabbits in Nevada, 225
Pigeons, band-tailed, trapping, 411
Ponds, productivity of Oklahoma farm, 450
Populations
brook trout in Maine, 336
diseases and parasites in peak jack rabbit, 225
isolated varying hare, 54
pheasants in Iowa, 136
prairie chicken, 233
Porter, Richard D. The Hungarian partridge in Utah, 93
Prairie chicken abundance, 233
Predation on fish by otter in Michigan, 497
Predator control in Missouri, 272
Progulske, Donald R. Game animals utilized as food by the bobcat in the southern Appalachians, 249
Punch-card bibliographic file, 472

Quail, food habits, 281

Rabbit
brush, reproduction in California, 177
cottontail, introduction and distribution in Oregon, 184
cottontail, restocking, 61
cottontail, trap response and census, 416
cottontail, use of bicolor lespedeza, 324
European, dangers of introduction, 8
jack, diseases and parasites in, 225
snowshoe, population in Virginia, 54
Raccoon
infestation of blow flies in, 499
reproduction in Texas, 409
Radiation, solar, and prairie chicken abundance, 233
Rainfall
and prairie chicken abundance, 233
and mallard production, 36
Randall, Robert N. Mourning dove production in south central North Dakota, 157
Raney, Edward C. and William S. Woolcott. Races of the striped bass in southeastern United States, 444
Range
deer appraisal, 358
Rocky Mountain goat in Montana, 429
utilization of wilderness, by big game, 206, 215
Redwood, damage to, by black bear, 437
Reid, George K. Jr. Book review, 398
Reilly, James R., see Herman, Carlton M., 402
Reproduction
brush rabbit, 177
calcium in pheasant, 325
raccoons in Texas, 409
Research, future of conservation, 1
Reviews, 147, 312, 398, 486
Richter, Wilmer C. A technique for night identification of animals, 159
and Stephen A. Liscinsky. Technique for identification of woodcock at night, 501
Ricker, William E. Book reviews, 487
Robinette, W. Leslie, Jay S. Gashwiler, Dale A. Jones and Harold S. Crane. Fertility of mule deer in Utah, 115
see Jensen, Wallace, 503
Roof, Lloyd, see Davison, V. E., 302
Rosene, Walter Jr. Bicolor as a rabbit food, 324
Recommendations for culture of *Lespedeza bicolor*, 84
Rupp, Robert S. Studies of the eastern brook trout population and fishery in Sunkhaze Stream, Maine, 336
Ryder, Richard A. Fish predation by the otter in Michigan, 497

Sampson, Frank W. and Allen Brohn. Missouri's program of extension predator control, 272
Saunders, Jack K. Jr. Food habits and range use of the Rocky Mountain goat in the Crazy Mountains, Montana, 429

Schofield, Raymond D. Analysis of muskrat age determination methods and their application in Michigan, 463
Sciple, George W., see Bell, J. F., 352
Sex determination in sage grouse, 267
Sheldon, William G. Methods of trapping woodcocks on their breeding grounds, 109
Shelford, V. E. and R. E. Yeatter. Some suggested relations of prairie chicken abundance to physical factors, especially rainfall and solar radiation, 233
Shetter, David S. and Marvin J. Whalls. Effect of impoundment on water temperatures of Fuller Creek, Montmorency County, Michigan, 47
Shuman, Richard F. Obituary, 309
Sibley, C. G. Book review, 400
Skoog, Ronald O., see Lensink, C. J., 364
Smith, Allen G. and Harry R. Webster. Effects of hail storms on waterfowl populations in Alberta, Canada—1953, 368
Solar radiation and prairie chicken abundance, 233
Spindler, John C. Loss of game fish in relation to physical characteristics of irrigation-canal intakes, 375
Squirrel
  fox, census, 89
  gray, age determination of, 479
  gray, skin tumors on, 402
Steenis, John H., see Aldrich, John W., 317
Stewart, Paul A. and Eugene H. Dustman. The use of auditory stimuli for flushing ring-necked pheasants, 403
Swenk, Wendell G. Feather molt as an ageing technique for mourning doves, 412
Swanson, Gustav A. Book review, 312

Tagging, returns on TVA reservoirs, 500
Tanner, James T. Map grids for field notes, 156
Texas, reproduction of raccoon in, 409
Thomas, D. Woods and Jerome K. Pasto. A theoretical framework for understanding the deer management problem, 143
Thompson, Harry V. The wild European rabbit and possible dangers of its introduction into the U.S.A., 8
Trapping
  band-tailed pigeons, 411
  blue and snow geese, 315
  cottontails, 466
  ruffed grouse, 405
  woodcock, 109, 405
Trout, brook, in Maine, 336
Turkey, wild
  albinism in, 408
  brood survival in, 408

Uhlig, Hans G. The determination of age of nestling and sub-adult gray squirrels in West Virginia, 479
Utah
  Hungarian partridge in, 93
  mule deer in, 115

Virginia, varying hare in, 54

Wallen, I. E. Some limnological considerations in the productivity of Oklahoma farm ponds, 450
Waterchestnut control, 504
Waterfowl
  banding, 71, 75
  management in southeast, 494
  marking, 316, 317, 319
  production, effects of fluctuating water levels on, 13
  production, effects of hail storms on, 368
Water temperatures, effect of impoundment on, 47
Weather and fall pheasant populations in Iowa, 136
Webster, Harry R., see Smith, Allen G., 368
West Virginia, gray squirrels in, 479
Whalls, Marvin J., see Shetter, David S., 47
Wilderness big game range utilization, 206
Wildlife Society, The
  Nominations for offices, 505
  Reports of officers and committees, 387
Winston, Frank A. Color marking of waterfowl, 319
Wisconsin, data on pheasants in, 150
Wolf, Ken. Some effects of fluctuating and falling water levels on waterfowl production, 13
Wood, A. J., see Cowan, I. M., 154, 331
Wood, John E. Notes on reproduction and rate of increase of raccoons in the Post Oak region of Texas, 409
Woodcock
  identification at night, 501
  trapping, 109, 405
Woolcott, William S., see Raney, E. C., 444
Wooten, William A. A trapping technique for band-tailed pigeons, 411

Yeatter, R. E., see Shelford, V. E., 233
Yukon, black brant in, 321

estling
ia, 479

ions in
, 450

levels

on, 47
wa, 136
3

owl, 319

l falling

rate of
egion of

4
que for